POLITECNICO DI TORINO

Master of Science in Engineering and Management

Master Thesis

Supply Chain 4.0:
Digital Maturity Model

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1 ABSTRACT

This thesis was realized during my internship experience in the Strategic Services team of JDA Software, leading supply chain software provider.

This paper addresses the theme of Digital Transformation and how it influences industries' supply chains.

In the first part of the paper, the description is realized through an analysis of the main current disrupting technologies and related implications which are playing important roles during this Industry 4.0 age.

In the second part of the paper, it is described how JDA is facing this Digital Supply Chain 4.0 transformation through an overview of its digital product portfolio, called *Luminate*^{TM}.

A Digital Supply Chain Maturity Model offering for JDA is developed in order to assess a client's digital readiness to implement *Luminate*^{TM} solutions along the core areas of this digital revolution. Thus, a more realistic transformation roadmap can be provided guiding JDA's clients towards the next digital maturity level.

2 Supply Chain embracing a Digital Future

Supply chains are the lifeblood of any business. They impact everything: quality, delivery, costs of a business's products and services, but also customer service, profitability, return on investment, customer satisfaction and much more.

In this V.U.C.A.[1] world (Volatile, Uncertain, Complex and Ambiguous), the old challenge - to get the right product, at the right time, at the right place and at the lowest cost - gets more and more complicated forcing companies to innovate and adapt permanently to remain competitive and succeed. Unfortunately, most supply chain organizations are still fragmented and operating in functional silos following

[1] V.U.C.A. is the acronym coined by the U.S. Army in the 1990s to describe the post-Cold War world: volatile, uncertain, complex and ambiguous. The idea of VUCA has been embraced by leaders in all sectors of society to describe the nature of the world in which they operate: the accelerating rate of change (volatility), the lack of predictability (uncertainty), the interconnectedness of cause-and-effect forces (complexity), and the strong potential for misreads (ambiguity). (Forsythe, 2018)

the traditional, inflexible system built for another era: "Plan-Source-Make-Deliver-Return" where each step is highly dependent on the previous one, therefore inefficiencies in one step create cascade effects on the following ones. They focus on optimizing just one aspect of the supply chain (not the entire value chain), and they are not able to better predict and mitigate disruptions imbalance due to the lack of transparency and visibility needed.

Traditional supply chain has lack of certain attributes that are needed in today's and tomorrow's business requirements. Low cost and on time delivery are not enough anymore to win in today supply chain world, where production is driven by customer demand not by manufacturing efficiencies.

Today digital savvy customer is in the driving seat on the roads of this omnichannel[2] world, where personalization and unique buying experiences are always expected. A consumer who is hyper-connected (24/7), more knowledgeable than ever before about how to best use the latest digital technologies, and who is getting used to buy anything, from anywhere, at anytime with a delivery to any location worldwide within a short timeframe.

The ever-evolving need for something new drives faster product development, giving most products a shorter life span and requiring a steady reconfiguration of supply chains.

As a result, the traditional linear supply chain has turned into a grid-based network to support the many different fulfillment options desired by the consumer

[2] Omni-channel is a term used to describe retail operations and shopping journeys that flow seamlessly across multiple channels. (Usie, 2016)

(who is the center), as well as the variety of ways that product can move across organizations. (Rotenberg, 2016)

Figure 1: Linear supply chain versus digital supply chain

In this ecosystem organizations can better interact with each other, send and receive data and information to and from any point. This allow to better meet changing market conditions and unlock new form of values through partnership and multidirectional communication among areas that were disconnected in the traditional system. (Laaper Y. W., 2018)

Globalization, increasing market volatility, higher customers' expectations, increasing costs and risks of supply chain and omnichannel solution, real time data availability, disruptive digital and technology platforms are changing and challenging the way retailer and manufacturing companies can manage their supply chain. (Bhatti, 2017)

2.1 A Cyber-Physical Age

2.1.1 Digital Supply Chain

Some companies around the world are re-thinking and transforming their supply chains into digital ones, always aiming at satisfying customer demand on time and at the minimum costs.

A study by The Boston Consulting Group shows that the leaders in digital supply chain management are enjoying increases in product availability of up to 10 percentage points, more than 25% faster response times to changes in market demand, and 30% better realization of working-capital reductions, on average, than the less nimble competitors. They have 40% to 110% higher operating margins and 17% to 64% fewer cash conversion days. (Ganeriwalla, 2016)

There are several different definitions of Digital Supply Chain (DSC).

The Digital Supply Chain Initiative describes the DSC as a customer-centric platform model that captures and maximizes utilization of real-time data coming from a variety of sources. It enables demand stimulation, matching, sensing and management to optimize performance and minimize risk. (Initiative, 2015)

According to Accenture, a DSC is rapid, scalable, intelligent and connected. Those characteristics are enabled by six core building blocks (Bhatti, 2017):

- Consumer-driven supply chains, that are rapid and responsive, in which end-consumer demand is aligned with supply realities;
- An integrated supply chain operating model, that breaks down silos and provides visibility and connectivity across the end-to-end supply chain;
- Performance management, that is aligned across the organization;
- Clear and differentiated supply chain segmentation strategies, to maintain operational efficiency and flexibility;
- End-to-end collaboration capacities within the organization and across external trading and service partners for faster decision-making;
- Digital capabilities and technology platform, that are cloud enabled with cognitive capabilities and real time connectivity.

Deloitte proposes a digital supply network (DSN) that is dynamic and integrated. This flexible and interconnected matrix-like design DSN is characterized by a continuous flow of information that moving non-linearly facilitates automation, adds value, improves workflow and analytics, and generates insights.

With the ability to ascertain information in real time, many of the latency challenges inherent in linear supply chain can be avoided.

Always-on agility, connected community, intelligent optimization, end-to-end transparency and holistic decision-making are the main characteristics attributed to the DSNs. (Laaper G. M., 2016)

2.1.2 Industry 4.0

The convergence of breakthrough technologies and dramatic shifts in consumer behavior are quickly transforming productions processes and business models across different industries pushing companies to create value in new and different ways.

In the world of manufacturing, technology advancements are so radical that they are defined the fourth industrial revolution which is based on the cyber-physical systems, Internet of Things and networks.

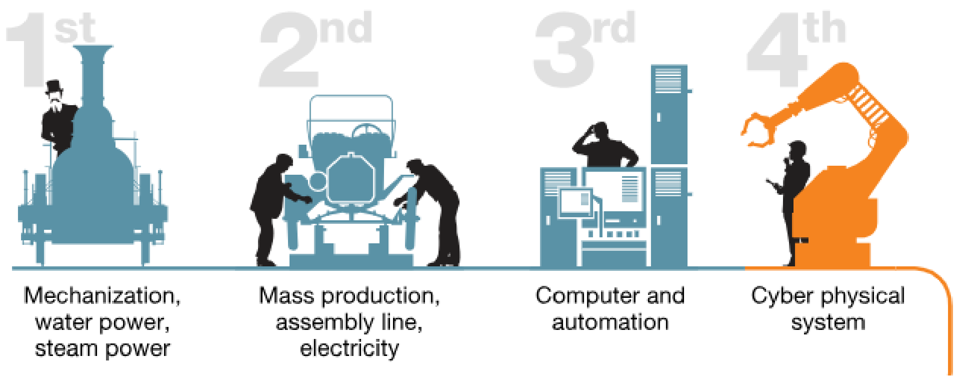

Figure 2: The fourth industrial revolution

The so called "Industry 4.0" is about the increasing connectivity of smaller and smaller components. Using data collected by physical objects, it impacts how these things themselves are manufactured. The more information is gathered, the more effective the manufacturing process become. Physical things and digital world create a feedback loop that gives manufacturers information to optimize every stage of the production process, improve quality, save time and money. Selling the completed products needs also to be taken into considerations because analyzing retail information can give real-time insights into which components or products sell best. (Podgoršek, 2017)

2.2 Digitization, Digitalization and Digital Transformation

Before introducing some of these disruptive technologies that are blurring the lines between physical and digital worlds, it is important to define the distinct terms that are often confused with each other, but they form a pattern of progress: first digitization, then digitalization and lastly digital transformation. (Irniger, 2017)

Figure 3: Digitization, Digitalization, Digital Transformation

"Digitization" essentially means converting the form that data is stored from analogue to digital. For instance, transferring paper-based document into computer or digital platform. This is a technology-centric approach where business value and transformational potential are not captured.

A step forward is “Digitalization” that captures value by exploiting digitization and underlying technologies, therefore it can be considered as a transformation- and value centric-approach.

The partial or complete change of a business model based on digitalization is defined as “Digital transformation”. It impacts products and services, processes, organizations and individuals. (Satzger, 2017)

For instance, Netflix, an American media-services provider, changed the way it creates value for the customer by offering movies on online libraries. This is a shift from shop to streaming. It changed the way it interacts with the customer. The customer does not need to ask anymore advice to the salesperson, but Netflix automatically recommends movies a customer might want to watch based on collected data on customer behavior (i.e. what genres he/she likes watching, what links he clicks or which statuses she is reacting to, etc.).

2.3 Behind this Digital Overhaul:

2.3.1 Big Data

Big Data refers to datasets characterized by the four Vs (Satzger, 2017):

- Volume (i.e. tremendous amount of data);
- Velocity (i.e. continuously growing via real or near-real time data acquisition);

- Variety (i.e. different data types: structured and unstructured data);
- Veracity (i.e. the degree of truth into the data).

According to IBM, 2.5 Quintillion bytes of data are created every day. Those data are generated internally or externally and can be both structured and unstructured (email, audio, video, picture, etc.); the latter is also defined as “dark” because it is noisy, or formats cannot be read by traditional systems. Unstructured data accounts for 80% of all data generated today and is expected to grow to over 93% by 2020. This just means a huge unfulfilled value. (Trice, 2015)

Exploiting in the right way accurate and high-quality Big Data through advanced analytics techniques allows to generate new insights for better and faster decision making, and to better understand preferences and pattern behavior of the customer and end-customer in a more sophisticated way to enhance also forecast, customer experience and service level.

This could turn into a source of competitive advantage.

What contributes the most to those fast-growing Data is Internet of Things.

2.3.2 Internet of Things

The Internet of Things (IoT) is the network of physical objects (e.g. devices, home appliances, vehicles, etc.) embedded with technology such as electronics, sensors, software, actuators, and network connectivity that enable these items to connect and exchange data. This results in improved efficiencies, accuracy, performance, and economic benefits. The opportunities for integration of the physical world into computer-based system are enabled by the capability of all these objects of being accessed or controlled remotely across the network.

Looking to the future, McKinsey Global Institute Research estimates that the impact of the Internet of Things on the global economy might be as high as $6.2 trillion by 2025. (Bauer, 2014)

Cisco System Inc., an American multinational technology company, predicts there will be 50 billion of devices connected by 2020. (Evans, 2011)

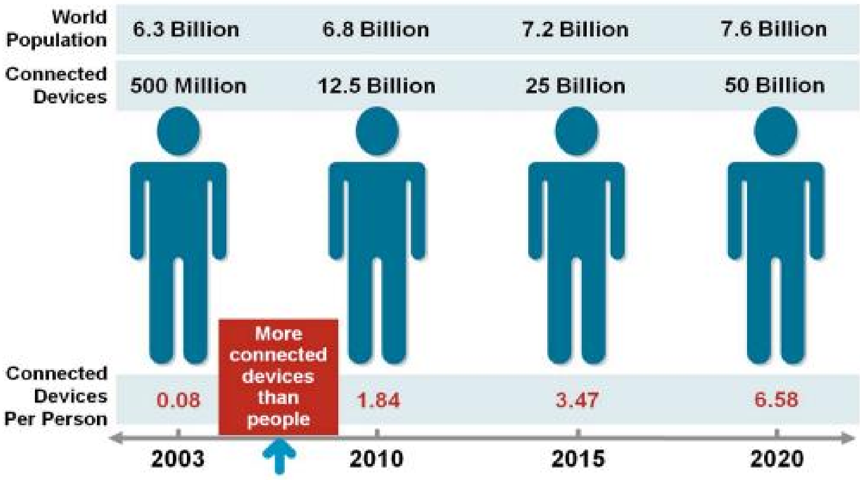

Figure 4: Internet of Things prediction

What is making a splash in the IoT is Artificial Intelligence.

2.3.3 Artificial Intelligence, Machine Learning and Deep Learning

The definition of **Artificial Intelligence** (AI) is constantly evolving, and the term often gets mangled.

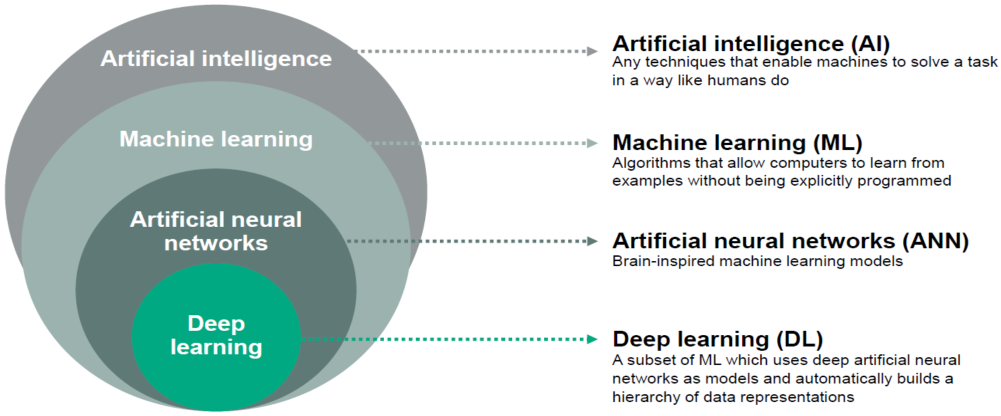

Figure 5: AI intra-relationships

"Is this AI?" is the title of The Massachusetts Institute of Technology (MIT) Technology Review article where AI is defined as the ability of machines to perform cognitive functions such as learn, reason, and act for themselves. They can make their own decisions when faced with new situations, in the same way that humans and animals can. (Hao, Is this AI?, 2018)

Nowadays the main six domains of AI investigation are (Desbiolles, 2018):

- Knowledge management;
- Language;
- Voice;
- Vision;
- Complex reasoning,
- Empathy.

AI is having dramatic impacts on supply chain decision making, reducing costs, improving service elements, and speeding inventory turns.

Some of the most promising application are (Taylor, 2017):

- Improving demand prediction to better match supply with demand at lower cost, less asset investment and with better response time;
- Predicting maintenance needs in manufacturing and transportation;
- Checking warehouse stocking levels to trigger re-orders;
- Managing transportation mode and carrier selection by transaction;
- Managing and/or mitigating risk and disruption.

As it currently stands, the vast majority of the AI advancements and applications today refers to a category of algorithms known as **Machine Learning** (ML). These algorithms use statistics to find patterns in massive amounts of data. Applying to small datasets does not allow to achieve good results. After detecting patterns, ML algorithms learn how to make predictions and recommendations by processing data and experiences, rather than by receiving explicit programming instruction. The algorithms also adapt in response to new data and experiences to improve efficacy overtime. (Hao, 2018)

There are three major types of ML (Mckinsey):

- Supervised Learning: it is an algorithm using training data and feedback from humans to learn the relationships of given inputs to a given outputs (e.g. how the inputs “time of the year” and “interest rate” predict housing prices.). An example of supervised learning algorithm can be the “Gradient-boosting trees” used to forecast product demand and inventory level;

- Unsupervised Learning: it is an algorithm that explores input data without being given an explicit output variable. For instance, recommendation systems like Spotify or YouTube can use this type of algorithm to suggest songs a customer might want to listen to based on customer preferences;
- Reinforcement Learning: it is an algorithm that learns to perform a task simply by trying to maximize rewards it receives for its actions, essentially learning by trial and error (e.g. maximizes points it receives for increasing returns on investment portfolio). Google DeepMind has used reinforcement learning to develop AlphaGo, a system that can play video games and board games better than humans: it defeated legendary Go player Lee Se-dol in 2016.

An advanced specialization within ML is **Deep Learning** originated by Geoff Hinton in 2006. It uses the model of artificial neural networks to make its predictions about new datasets. They are defined neural networks because their structure and functions are inspired by that of the human brain.

It is estimated that 40% of all the potential value which can be generated by analytics today comes from Deep Learning, which could account for between $3.5 and $5.8 trillion in annual value. (Chui M. M., 2018)

An example of the progress of this algorithm can be found in the results of the annual ImageNet Large Scale Visual Recognition Challenge (*Figure 6*).

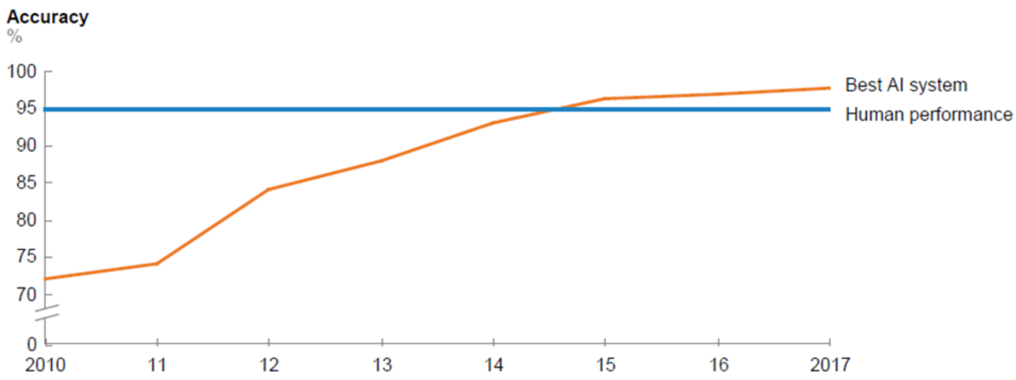

Figure 6: AI exceeding human performance

Since 2010 ML researchers have competed by submitting algorithms for recognizing objects within a public database of 14 million labeled images. The increase in accuracy observed in 2012 is widely considered the harbinger of the deep learning revolution. For the first time a deep neural net was used to address the problem and showed dramatic improvement over previous efforts. The accuracy of the best-performing algorithms (all now using deep learning) now exceeds "human level performance", the accuracy level expected of a human performing the same task. (Chui M. M., 2018)

AI technologies have plenty of limitations that need to be overcome.

Five challenges stand out (Chui M. M., 2018):

- Labeling training data for supervised learning (often done manually);
- The difficulty of obtaining sufficiently large and comprehensive datasets used for training;

- The difficulty of explaining in human terms results obtained from complex models;
- The Generalizability of learning since AI models still have difficulties in carrying their experiences from one set of circumstances to another;
- The risk of bias in data and algorithms because if AI models are applied incorrectly, they could perpetuate existing social and cultural bias.

As a result, only 20% of AI-aware firms is using one or more AI applications in a core business process or at scale. (Chui M. M., 2018)

2.3.4 Advanced Analytics

Advanced analytics is the process and technology used to make sense of large amounts of data that helps companies to uncover pattern and insights from data to differentiate, drive innovation and pursue breakthrough ideas. It can have positive impact at any scale, addressing most any problem.

Data analytics comprises the following three main phases (Satzger, 2017):

- Analytics 1.0 is the traditional Business Intelligence that answers the question "What happened?" (Descriptive analytics). It provides greater level of visibility for both internal and external systems and data by the examination of historical data;
- Analytics 2.0 is around Big data, examining massive amount and different types of data;

- Analytics 3.0, so-called "Advanced analytics", is the once that ML focus on offering higher value to the customers.

Besides examining the past events, advanced analytics forecast also future events answering to the questions (McGovern, 2017):

- "What might or will happen?": Predictive analytics helps identify the most probable outcomes of future scenarios and related business implications to be able also to mitigate disruptions and risks;
- "What should we do about it?": Prescriptive analytics extends beyond descriptive and predictive analytics by specifying the decision options available to take advantage of the results gathered in the previous phases. It looks at both the actions necessary to achieve predicted outcomes or mitigate risk and the interrelated effects of each decision.

Prescriptive analytics is not a step forward predictive analytics: it is possible to do just prescriptive analytics without any predictive analytics in place.

For instance, Tesco, a multinational grocery retailer, was able to save approximately $140 million mainly through the reduction of wasted stock. It fed weather data into its predictive analytics tool to forecast demand of weather-dependent products (e.g. ice-cream), and adjusted inventory and supplier orders in advance on a store-by-store basis to minimize missed revenue. (Gish, 2016)

The main drivers that boost the development of advanced analytics are (Satzger, 2017):

- The availability of “Big data” (generated by Sensors, Social Media);
- The availability of support and enablement (advanced methods and software tools);
- The availability of capabilities (“Data Science” education);
- The availability of complementary technologies (Cloud, Mobile, Social Computing);
- The focus on organization-spanning view (service systems).

Advanced analytics sets the stage for Cognitive Computing.

2.3.5 Cognitive Computing

Cognitive Computing is a technology, based on machine learning and very sophisticated natural language processing, which attempts to mimic the functions of the human brain, but at a huge capacity and speed, trying to improve on the human decision-making process since it repeatedly learns by experience, adapts, builds knowledge and improves overtime. It does not offer decisive answers, but it weights information from multiple sources, reasons, and then offers hypotheses, a confidence level to each potential insight.

Cognitive systems can handle massive amounts of complex unstructured (and structured) data, discovering actionable insights unlike human intelligence or traditional systems can do.

When cognitive systems are combined with basic strengths of digital computing, they can help solve problems with higher accuracy, more resilience and on a massive scale over large bodies of information. (Miller, 2017)

International data corporation (IDC), a global provider of market intelligence for the IT market, in a study that forecasts worldwide information technology (IT) industry predictions for 2016 predicts that, by 2020, 50% of all business analytics software will incorporate cognitive computing functionality. (Gens, 2015)

2.3.6 Cognitive Manufacturing

Cognitive Manufacturing or Smart Manufacturing is the application of cognitive capabilities (natural language and sensory-based capabilities) and current production technologies (IoT, robotics, analytics, etc.) to digitize and optimize areas of manufacturing process that were previously inaccessible.

It creates new interactions between humans and machines.

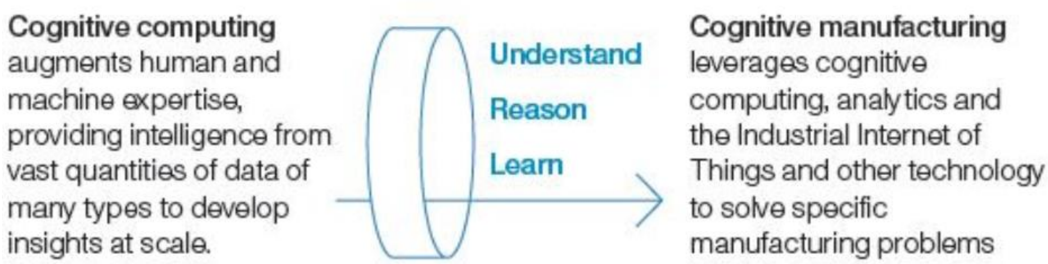

Figure 7: Cognitive computing and cognitive manufacturing

Organizations that have a good understanding of advanced analytics and the Industrial IoT are prepared to embrace cognitive manufacturing more quickly than others.

The three key pillars of manufacturing on which early adopters are focusing and obtaining huge benefits are (Miller, 2017) :

- Intelligent assets and equipment: optimizing performance and reducing downtime by using connected sensors, cognitive capabilities and analytics;
- Cognitive processes and operations: enhanced quality, operations and decision-making process by analyzing different information from workflows, process and environment;
- Smarter resources and optimization: optimizing resources (labor, energy, etc.) by combining a variety of data from individuals, usage, locations, expertise with cognitive knowledge.

The key success factor is having a well-documented smart manufacturing strategy that includes (Lewis, 2017):

- Strategic imperatives and key drivers;
- Long-term vision;
- Business case;
- Competitive advantage;
- Targeted business and manufacturing processes;
- Technology baseline and desired future state;
- Analytics and automation skills assessment;
- Talent management and human resources;

- An executive sponsorship.

2.3.7 Cloud Computing

Cloud computing is the delivery of computing services, such as servers, storage, databases, and other services, over the internet ("the Cloud") to offer faster innovation, flexible resources and economies of scale. It's either pay-per-use or advertising based, and it allows to make data readily accessible from virtually any location, therefore minimizing capex costs related to infrastructure and maintenance in information technology. There are three types of Cloud services: Software-as-a-service (SaaS); Platform-as-a-service (PaaS), and Infrastructure-as-a-service (IaaS); and three cloud deployment models: private cloud, public cloud and hybrid cloud. (Microsoft)

Organizations turning to cloud computing services obtain several benefits, some of them are:

- Higher security of data, applications and infrastructures from potential threats;
- Reduced network latency and faster time to value;
- Agile deployment, configuration and integration;
- Higher productivity, performance, and speed of process.

2.3.8 Blockchain

Originally developed for the digital currency of Bitcoin, Blockchain is a distributed database of transaction continuously growing which is shared among an agreed upon peer-to-peer network. It consists of a linked sequence of blocks, holding timestamped transactions that are secured by public-key cryptography and verified by the network community. Once an element is appended to the blockchain, it cannot be altered, turning a blockchain into an immutable record of past activities without the control of any central authorities or intermediaries (e.g. bankers, insurers, brokers). Cryptography and digital signatures ensure authenticity, proof-of-work and validity of data. (Satzger, 2017)

This trustworthy platform could tackle the problem of trust between different supply chain parties that is usually developed over time as companies and suppliers work successfully together. Thus, onboarding of new suppliers could be much faster and more efficient, with less time spent on due diligence.

By offering a more decentralized approach to data sharing and management, blockchain helps to improve transparency, speed and responsiveness of today complex supply chain ecosystems.

Other benefits for supply network are the following (Laaper Y. W., 2018):

- Increased traceability of material supply chain to ensure corporate standards are met;
- Reduced losses from counterfeit/gray market trading;
- Improved visibility and compliance over outsourced contract manufacturing;
- Reduced paperwork and administrative costs.

The key is knowing whether and how to capitalize on a blockchain, when to combine it with other digital technologies for even greater synergies, and how to weight its cost/value tradeoffs relative to those of other advanced supply chain management approaches. (Bender, 2018)

3 WHAT FOLLOWS:

3.1 Change Management

No transformation is problem-free.

Before realizing the full potential of the digital supply chain, companies might face several internal and external challenges since the approach to transition from a traditional to a digital is not obvious because there is not just one single path that organization can take toward digital innovations.

As Harvard Business Review senior editor Andrea Ovans says, “The question we should be asking is not what utterly unpredictable new things will turn up to annihilate your business but what form of organization is appropriate to capitalize on them”. (Ovans, 2015)

Although shiny new technologies often receive attention, success in the digital journey depends on people. Leaders recognize that culture is both a barrier and an enabler of strategic business change. It is culture that drives behavior and determines success or failure of an innovation project, therefore a high level of commitment and the right mindset among the workforce and within company management is required to innovation culture. (Chadwick S. J., 2018)

Empowering teams of people across traditional functional structures is also central to become a more adaptive organization. (Chadwick, 2018)

In 2018 Deloitte jointly with the Manufacturers Alliance for Productivity and Innovation (MAPI) executed a digital supply network study. They surveyed 186 manufacturers companies: 34 small companies with less than $1 billion in annual revenue, 92 medium companies with $1 to $5 billion in annual revenue, and 60 large companies with $5 billion or more in annual revenue. (Laaper Y. W., 2018)

As shown in *figure 8*, smaller companies are investing more heavily in advanced analytics, while large companies are more focus on cloud solutions.

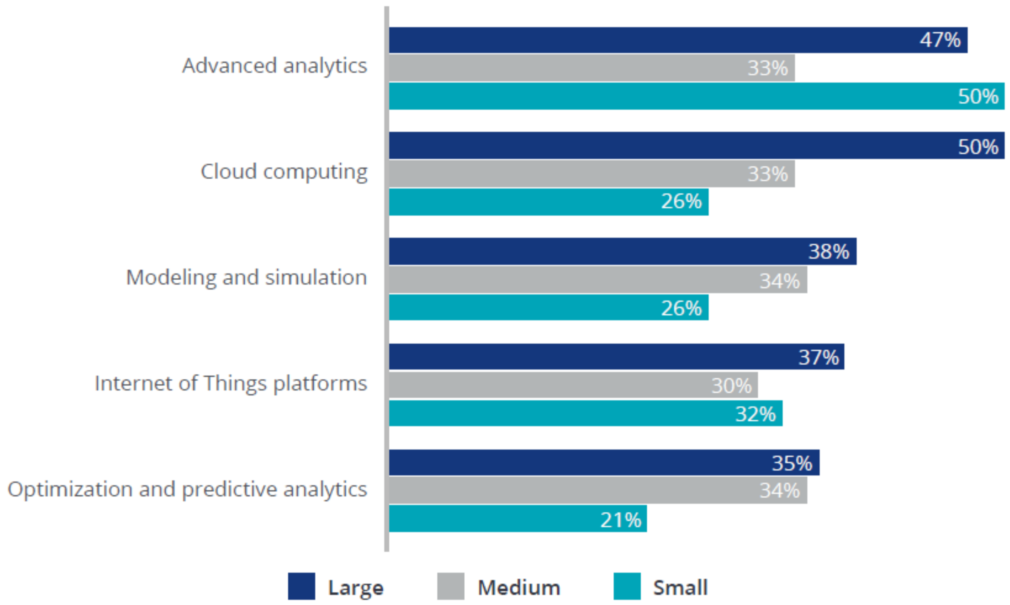

Figure 8: Top five technology investments by company size

The top ten biggest challenges that they faced with launching/executing digital supply chain initiatives were:

- 30% difficulty **finding talent** with the skills needed;
- 30% difficulty **training talent** for the right skills;
- 30% **inadequate** enterprise **data** management and architecture;
- 27% difficulty in **identifying starting point**, what is needed, and how to prioritize;
- 27% competing priorities and **misalignment of stakeholders**;
- 27% difficulty **keeping normal** operating system/procedures running smoothly **while** initiatives are **creating changes** to the very same system/procedures;
- 27% inability to **show full value benefits** of longer-term digital initiatives due to rigidity of traditional financial reporting cycle (e.g. quarterly);
- 26% difficulty getting **talent and technology to work together** efficiently;
- 26% lack of connectivity with other platform/network stakeholders/partners;
- 23% lack of **understanding** and/or buy-in from **senior executives**.

Organizations that are trying to navigate successful digital change initiative(s) should (Olding, 2018) (Steward, 2018):

- Understand and define what **digital means** to them to identify specific opportunity that digital represents;

- Form a **digital council**, led by one or more collaborative **senior leaders**, to define, sponsor and implement the digital opportunity;
- Ensure that the **"why"** of the change, **"what"** has to change, and **"how"** each role fits in the overall strategy are clearly defined, shared and **understood** among leaders of the business areas impacted, and **cascade** down to their respective teams and employees;
- Define an approach to **encourage innovation**, allowing all employees to participate in **strategic ideation**, further infusing enthusiasm and ensuring **engagement and adoption**;
- Develop a strong and clear **digital change vision**, assess digital maturity and capabilities, and then leverage an **organizational change management** methodology that recognizes the need for business agility;
- Use **Agile methods** for faster benefits realization, which further encourages support for digital efforts;
- **Grow digital talent** from within and leverage external support as needed:
- **Incentivize employees** by setting clear digital goals aligned with cross-organizational outcomes, and then recognize and reward their efforts;
- Build a **digital culture**, including open and **transparent communication** from the top, leveraging company-wide **collaboration** platforms and **e-learning** techniques to encourage wider engagement extensively communicating digital initiatives;

- **Include digital native**, “Millennials”, along with more senior managers; and engage them to monitor the latest disruptive technologies, identifying both potential threats and possible partnerships or acquisition opportunities;
- Collect **feedback** and answer questions coming from stakeholders that can be an early warning to avoid hang-ups, delays, misinterpretations or unanticipated risks.

3.2 Automation and New Skillset

Most important personal and professional human decisions, under uncertainty, are emotional. They cannot and will never be automated (e.g. founding a company, declining an offer, marrying, etc.).

While regularly operational decisions in enterprise can be 99% automated today (e.g. automating quantity order, price reduction, etc.). (Feindt, 2018)

“Thinking, Fast and Slow” is a book written by Daniel Kahneman, Nobel Prize winner in Economics. The first chapter describes as humans decision-making system is guided by two systems and has many biases.

System 1 is fast and emotional working autonomous, mechanical and unconscious; and it is error-prone. System 2 is slow, rational, and reliable; it requires deep thinking and more energy; therefore, it is hardly used or often only as a posteriori justification system. (Kahneman, 2011)

Most of the time humans use System 1 for everyday life decisions.

Even scientists and experts do many wrong decisions since they are humans and they also use the “fast” System, because they are not always thinking and rationally deciding.

System 1 cannot speak statistic, cannot really judge risks and chances and this leads to systematic errors in decision-making process; while an objective observer is more likely than humans to identify their theoretical errors. It improves the ability to identify and understand errors of judgment and choice that humans can make guided by impressions and sensations.

But this does not mean denigrating human intelligence. This idea highlights the need of synergy between humans and machines: artificial intelligence and the automation of repetitive routine white-collar work will free up time for workers to focus on higher-value activities with stronger strategic decisions, more efficient and sustainable. (Feindt, 2018)

Thus, the interaction of man and machine will produce capabilities going forward. This set up the idea of “men and machine”, not man versus machine. Today machines can do limitless ingestion of knowledge and large-scale calculations better than humans.

But humans have some abilities that machines will have, or maybe never, hard time replicating: critical thinking and soft skills. (Desbiolles, 2018)

The right skillset to face this digital age includes (Hume, 2018):

- “Fast-fail” mindset;
- Be able to reinvent yourself;
- Trust technology;

- Emotional resilience;
- Cross-skills on different tasks;
- Appreciation of statistics.

In a study conducted by James E. Bessen of Boston University was found out that “Employment grows significantly faster in occupations that use computers more, computer use is associated with about a 1.7% increase in employment per year. This association is true in general, and for occupations that perform more routine tasks and for mid-wage occupations.”

Automation and AI are not eliminating job roles; they are just changing the nature of tasks associated with many jobs. (Chui M. M., 2016)

3.3 Data Quality Assessment

Accurate and high-quality data is the necessary condition for obtaining the unfulfilled value hidden inside Big Data.

Quality is “the degree to which a set of inherent characteristics fulfill the requirement”. (G.A.Q.S., 2008)

The Total Data Quality Management group of MIT University led by professor R.Y.Wang has done in-depth research in the data quality area and they proposed a definition of data quality as “the fitness for use” (Wang, 1996) and data quality dimension as a set of attributes that represent a single aspect of data quality. They identified four categories containing fifteen data quality dimensions by using a two-stage survey.

According to the U.S. National Institute of Statistical Sciences (NISS), the principles of data quality are (Alan, 2001):

- Data are a product, with customers, to whom they have both value and cost;
- Being a product means having quality, resulting from the process by which data are generated;
- Data quality depends on different factors, including the purpose for which data are used, the time, the user, etc.

Poor data quality leads to low data utilization efficiency and higher probability of decision-making mistakes.

Big Data quality faces four main challenges (Cai, 2015):

- The difficulty of data integration due to the diversity of data source that generates enormous data types and complex data structures;
- The difficulty to judge data quality within a reasonable timeframe due to large data volume;
- The necessity of higher requirements for processing technology due to the fast-changing data and their short "timeliness";
- The lack of a unified and approved data quality standards of Big Data.

There is not a uniform definition of Big Data quality of its quality criteria.

The Professor Li Cai and Yangyong Zhu, University of California, proposed a hierarchical data quality standard for assessment from the perspective of the users. (Cai, 2015)

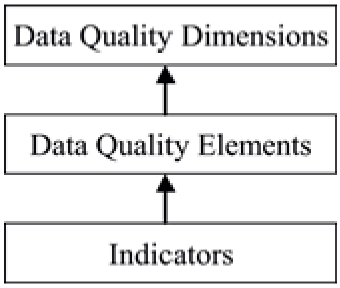

Figure 9: Data quality framework

They used Big Data quality dimensions widely used as standards and they redefined their concepts based on business needs. Each dimension was divided into many elements, typically associated with them, and each element with its corresponding quality indicators (*figure 9*).

Figure 10 depicts the universal, two layers Big Data quality standard for assessment that they created.

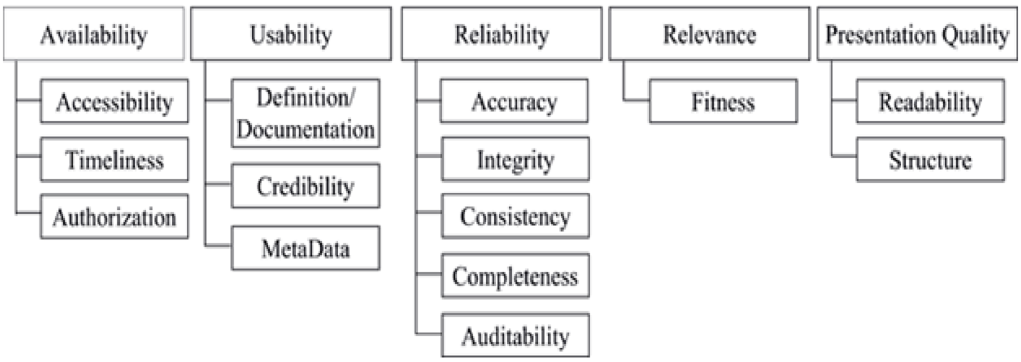

Figure 10: A universal, two-layer Big Data quality standard for assessment

The data quality standard is composed of five dimensions of data quality:

- Availability: the degree of convenience for users to obtain data and related information;
- Usability: the degree to which the data are useful and meet user needs;
- Reliability: the degree of trustworthiness inside the data;
- Relevance: the degree of correlation between data content and users' expectations or demands;
- Presentation Quality: it is an additional properties of data quality which refers to a valid description method for the data allowing users to understand better the data.

The first four are inherent features of data quality. Data quality elements for all the five dimensions are described in the Table below.

Dimensions:	**Elements**
Availability	• Accessibility: degree of difficulty for users to obtain data; • Timeliness: time delay from data generation and acquisition to utilization; • Authorization: whether an individual/organization has the right to use the data.
Usability	• Definition/Documentation: data specifications (name, range of valid values, etc.); • Credibility: objective/subjective components of the believability of a source;

	• Metadata: accurate description of Big Data to avoid misunderstanding and inconsistencies.
Reliability	• Accuracy: the measure of statistical bias; • Integrity: In a database it refers to data having complete structure; in information security it means maintaining and assuring the accuracy and consistency of data over its entire life-cycle; • Consistency: whether the logical relationship between correlated data is correct and complete; • Completeness: the values of all components of a single datum are valid; • Auditability: auditors can fairly evaluate data accuracy and integrity within rational time and manpower limits during the data use phase
Relevance	• Fitness: it has two-level requirements: the amount of accessed data used by the users, and the degree to which the data produced matches users' needs (indicators definition, elements, classification, etc.).
Presentation Quality	• Readability: ability of data content to be correctly explained; • Structure: level of difficulty in transforming semi-structured or unstructured data to structured data through technology.

The quality assessment process for Big Data proposed to draw valid conclusion is shown in *figure 11*.

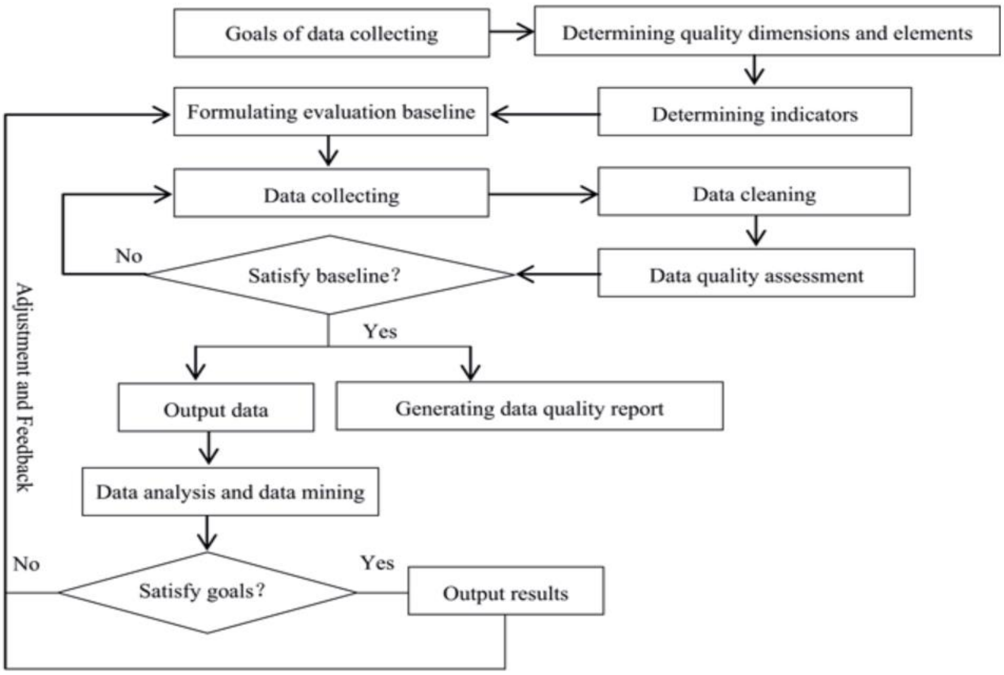

Figure 11: Quality assessment process for big data

This dynamic feedback mechanism follows eight steps:

- Define the goals of data collection;
- Define data quality dimensions and elements that differ based on the different business environments;
- Choose specific assessment indicators for every dimension;
- Determine the baseline of data quality dimensions by assessing dimensions with the most appropriate measurement tools, techniques and processes and choosing the ones that meet the needs;

- Start the data acquisition phase once the process assessment preparation is completed;
- Clean data to detect and remove errors and inconsistencies for better quality;
- Start the data quality assessment (qualitative or quantitative methods) and monitoring phases;
- Compare the data with the baseline for the data quality assessment established in the step above. If the data quality corresponds with the baseline standard, a follow-up analysis phase can be entered, and a data quality report will be generated. Otherwise, it is necessary to acquire new data.

Data analysis and data Mining (Statistics, AI, ML) are used to discover if there is any valuable information or knowledge inside Big Data to help business decisions, scientific discovery, policy proposals, etc. If the analysis is line with the goals, the outputted results are fed back to the quality assessment system in order to better support the next round of assessment. Otherwise, the baseline needs to be adjusted in a timely fashion to obtain results meeting the goals. (Cai, 2015)

3.4 Cyber Security

Resilience is the organizational capability to sense, resist and respond to disruptive events, adapting and reshaping operations in environments with foreseeable and unforeseeable risks. (Firth, 2017)

In this age where the pace of technological change is rapid that makes more challenging to predict risks and make companies reluctant to provide data to outside partners due to cyber vulnerability fear.

In order to address this cyber-related issue that limits the opportunity to fully develop a digital initiative, companies should (Laaper Y. W., 2018):

- Perform regular cyber assessments to ensure that company data are safe and operational risk is minimized;
- Take into account important source of cyber-risk in the planning stage of a digital initiative;
- Establish ongoing monitor of external partners to help ensure a level of acceptable cyber-risk through the ecosystem.

4 JDA SOFTWARE

JDA Software is an American software provider headquartered in Scottsdale, Arizona. It is a proven leader in AI/ML-driven supply chain and retail solutions for more than 4000 global customers (Coca-Cola, IKEA, Johnson & Johnson, Mercedes-Benz, P&G, Philips, etc.). It owns over 400 patents granted and pending, 4 Centers of Excellence, more than 40 locations worldwide with 4600 associates, 7 subsidiary companies (BlueYonder, RedPrairie, i2 Technologies, Manugistics, E3, Intactix, Arthur) and a strong partner ecosystem (Microsoft, Google, IBM, etc.).

JDA shows its market leadership by being named leader in all five "Gartner Supply Chain Magic Quadrants" which are: Supply Chain Planning, Sales and Operations Planning, Transportation Management, Warehouse Management, and Retail Assortment. (JDA, 2018)

JDA's end-to-end supply chain software (*figure 12*) and cloud-based solutions help companies to reduce costs, increase profitability and improve collaboration for a better fulfillment of customer demands.

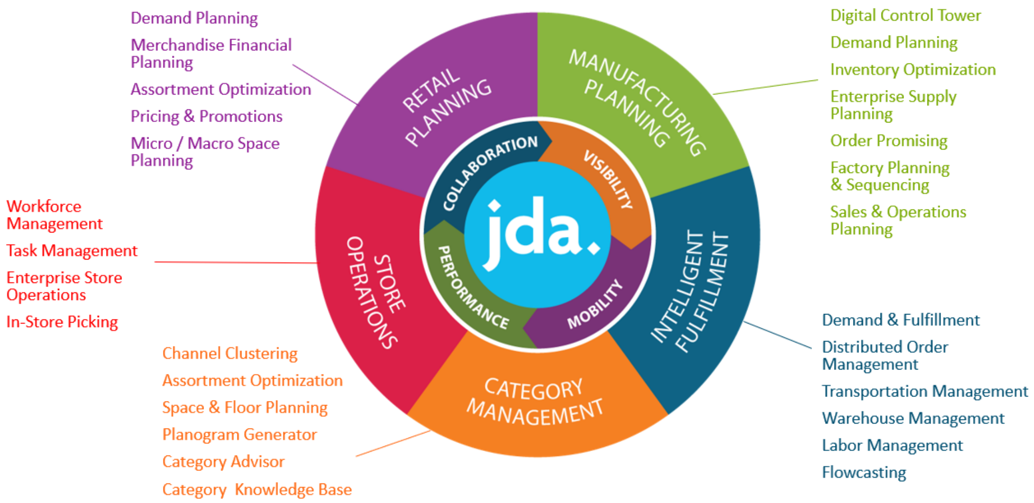

Figure 12: JDA's end-to-end Supply chain solutions

4.1 JDA's Digital Product Portfolio: Luminate^{TM}

In this digital transformation era JDA extends and enhances its product portfolio with a set of new next-generation solutions (*figure 13*), *Luminate^{TM}*, enabling a more agile supply chain transformation towards JDA's moonshot: the autonomous supply chain.

Luminate^{TM} is a cognitive, real-time, connected platform. It is generated by the combination of digital-edge technologies (SaaS, IoT, AI/ML, Advanced Analytics) and core existing applications, no-upgrade required. It seamlessly turns real-time data into fast, profitable business decisions by connecting stores, distribution centers, logistics and manufacturing in a digital network, matching demand and supply continuously, at every point of the supply chain.

This new-generation cloud-based approach uses machine learning, artificial intelligence, and social media, news, events and weather (SNEW) data coming from the IoT to gain greater customer insights, deliver better service, drive competitive differentiation and revenue growth deriving from the higher speed and automation with which decisions can be made now.

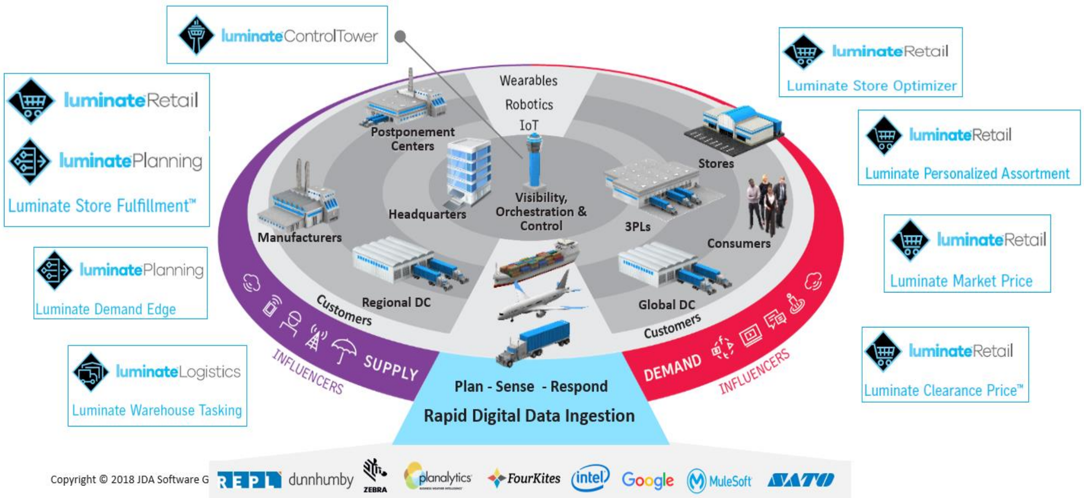

Figure 13: JDA LuminateTM Product Portfolio and Partner Ecosystem

Figure 13 depicts how the new JDA's digital ecosystem looks like. Its vision is to provide intelligent solutions that allow end-to-end digitalization of companies' supply chain across manufacturing, fulfillment, wholesale, distribution, warehousing and retail.

4.1.1 Luminate^{TM} Control Tower

The Digital Control Tower (*figure 14*) is a net new application and it plays an important and central role in JDA's vision. It is considered a nerve center since:

- It is a visibility platform that provides end-to-end visibility of supply chain status, activities, and KPIs, with dashboard for disruptions across the supply chain that need attention and some or most of the stakeholders may never see. The dashboard is customized to the level and activities of the user, but all drives from the same set of data;
- It is also a technology platform where both internal and external influences on the supply chain can be brought in and considered for action more efficiently and effectively (intelligent scenario planning);
- It is a communication platform that increases collaboration among upstream and downstream partners who deal with one version of the truth and resolve exceptions. This leads to coordinated response to internal and external issues across the supply chain, rather than each silo dealing with it sub optimally; and also higher customer service level and lower total cost to serve.

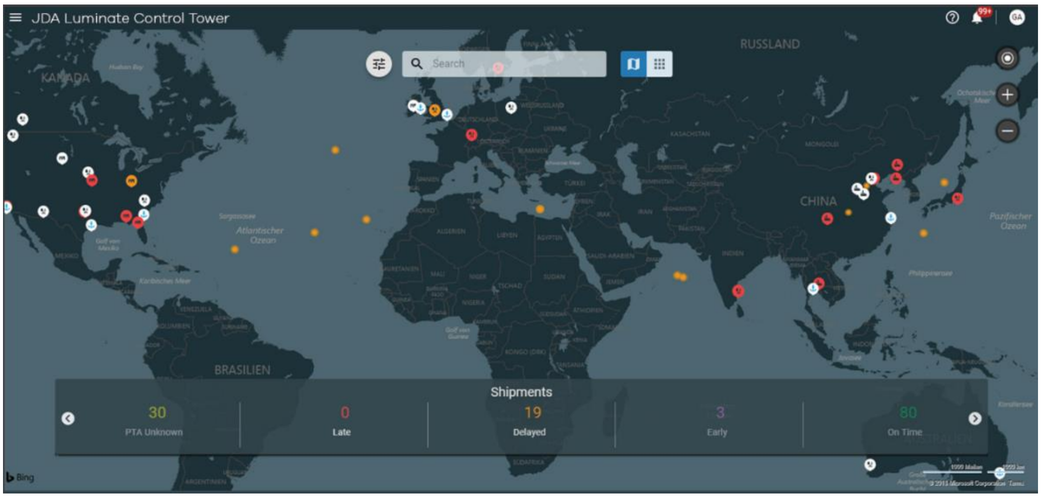

Figure 14: LuminateTM Control Tower Dashboard

4.1.2 Luminate^{TM} Warehouse Tasking

Luminate^{TM} Warehouse Tasking is an enhancement of JDA's Warehouse Management System (Logistics) running without interruption on Microsoft® Azure® cloud. Its tasking engine uses a powerful algorithm that adds an additional layer of capability in order to reduce unnecessary overtime costs and achieve higher efficiency through better resource utilization and tackle the problem of workforce visibility (deeper view into productivity and other labor parameters). As this solution evolves, the engine focuses workforce on the most important tasks at a given time. Tasks are assigned based on parameters the user defines, while the engine tracks task-related shift lengths and times the position of labor resources in near real-time. Dynamic allocation capabilities reduce travel time and pick items in the most effective way as new assignments come, even as conditions change.

4.1.3 Luminate^{TM} Store Optimizer

Luminate^{TM} Store Optimizer is built on Google Cloud Platform and delivers a complete view of store operations by unlocking data to optimize workflows and staff resources at every store for a positive in-store experience across locations. It has two modules:

- "Dynamic Task" is a planning and optimization tool that, integrated to the existing systems, provides advanced analysis and business process improvement. Objectives are always prioritized making it easier to respond to changing business challenges, keeping teams throughout organization on task and schedule constantly;
- "Dynamic Merchandising" groups tasks based on floor and space plans and stock room layouts reducing out-of-stocks and lost sales. Tasks are automatically generated with existing data feeds or with the addition of sensing technology. This solution groups and ranks merchandising tasks based on revenue contribution and importance to the company's business goals. When an important promotion or seasonal activity drives customers to the store, the system immediately prioritizes tasks, so the shelves stay stocked and the sales goals are met.

This Store Optimizer receives data feeds from a wide variety of sources, from POS and other systems to many types of sensors, including RFID tags, beacons, T-log, motion sensors and more ensuring greater inventory visibility and improved margins. This solution has also a simple, intuitive user experience design. Therefore, it is easy to learn and use with minimal staff training required.

The Retail and Planning Luminate™ solutions, that will be described in the following sections, are powered by Blue Yonder's proprietary algorithms.

BY approach will be explained later in the section "Blue Yonder's algorithms".

4.1.4 Luminate™ Clearance Price

Luminate™ Clearance Price is a powerful markdown pricing solution that goes beyond rule-based pricing and delivers data-driven, continuously optimized prices at the finest levels of granularity: store, product, color and size. It considers the costs and impacts of price changes, behaviors alongside product master data and external data feeds. Its continuous ML capabilities, combined with parameters the user provides, let the user execute the most valuable price changes for any given day, store and item.

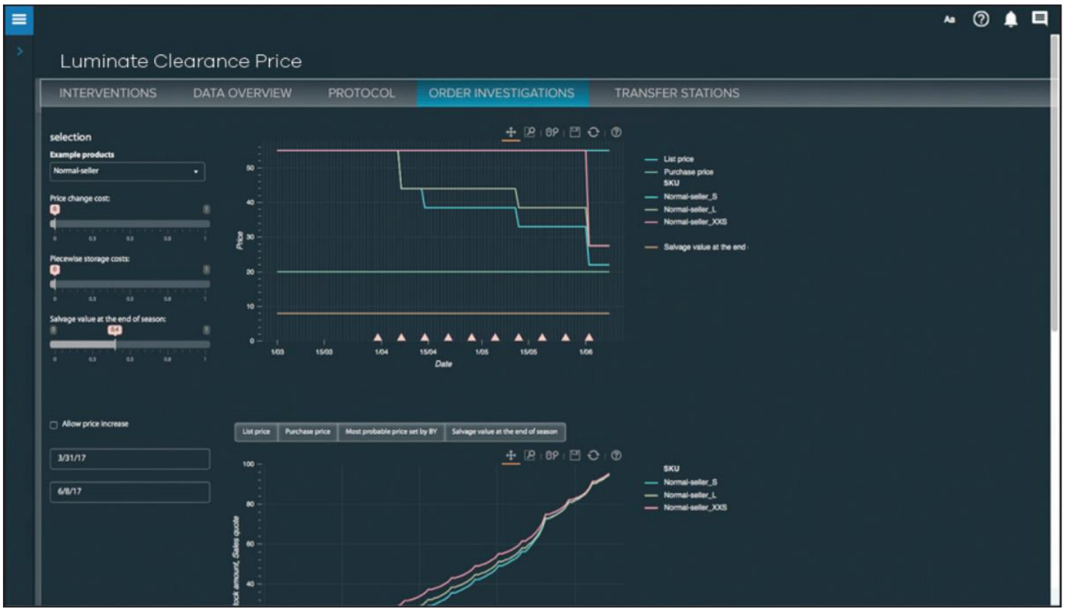

Figure 15: LuminateTM Clearance Price

4.1.5 *Luminate^{TM} Demand Edge*

Luminate™ Demand Edge extends and enhances traditional demand planning applications taking an outside-in forecasting approach. It delivers highly accurate, probabilistic short-term forecasts incorporating hundreds of internal and external demand factors, such as the impact of social sentiment, the weather, local events, news and IoT data, along with their complex interaction.

Thus, more risk-aware business decisions can be taken.

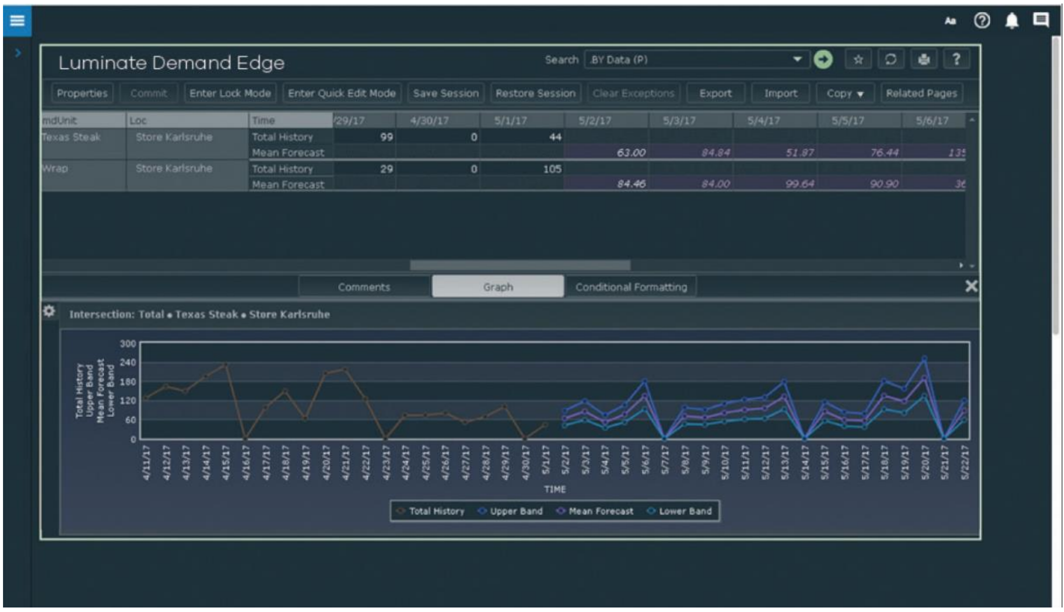

Figure 16: LuminateTM Demand Edge

4.1.6 *Luminate^{TM} Market Price*

Luminate^{TM} Market Price tests and measures interactions between price and demand changes. It automatically sets revenue- and profit-maximizing prices using current and historical data and product master data. With continuous optimization to align with all channel pricing, it allows to optimize hundreds of prices every day while considering the cost and effects of each change.

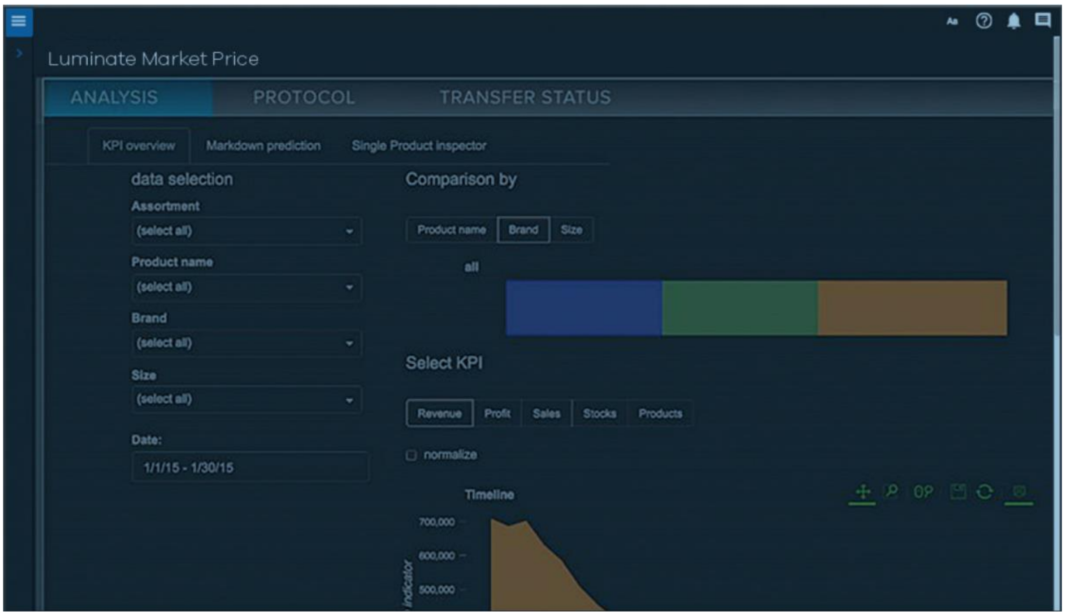

Figure 17: LuminateTM Market Price

4.1.7 Luminate^{TM} Store Fulfillment

Luminate™ Store Fulfillment creates accurate, granular demand forecasts, optimizing product availability while reducing waste and unnecessary manual interventions. It calculates demand and optimizes order decisions on the finest levels - per store, product and day. In addition, retailers can set desired quantities per product and store, driven by shelf sizes and presentational needs, and it will optimize towards that number wherever waste and lost sales constraints allow.

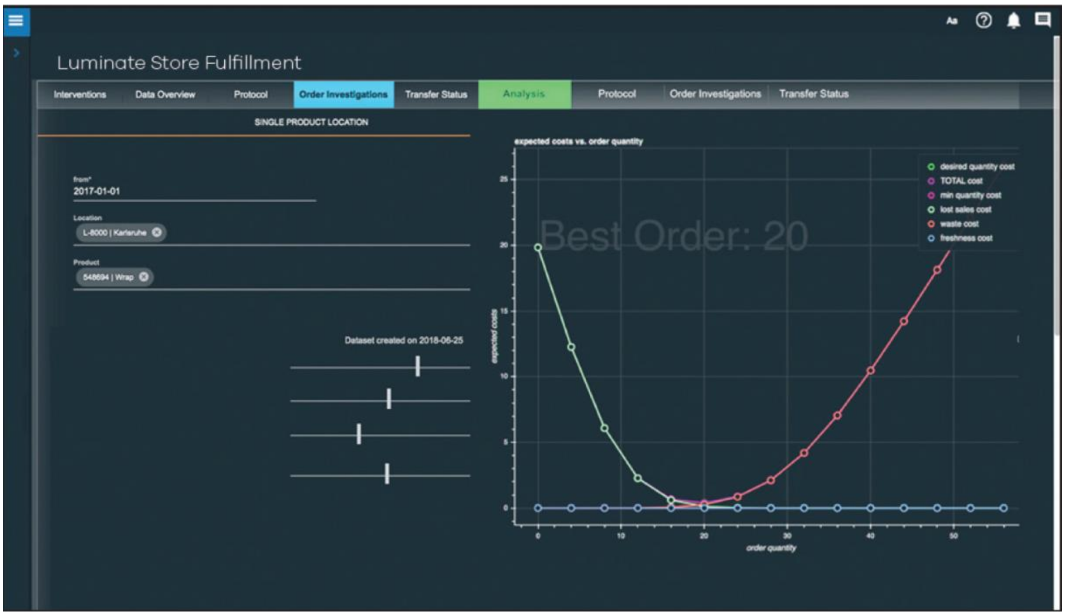

Figure 18: LuminateTM Store Fulfillment

4.1.8 Luminate^{TM} Personalized Assortment

Luminate™ Personalized Assortment is a solution for specialty and general merchandise retailers to leverage their data sources to deliver localized offers.

It analyzes data from buying patterns to predict demand for each item, then it converts this forecast into a relative score, enabling planners to align product selection with customer preferences. This maximizes sales, margins and inventory productivity by aligning purchase plans, ranges and pre-positioned inventory by location.

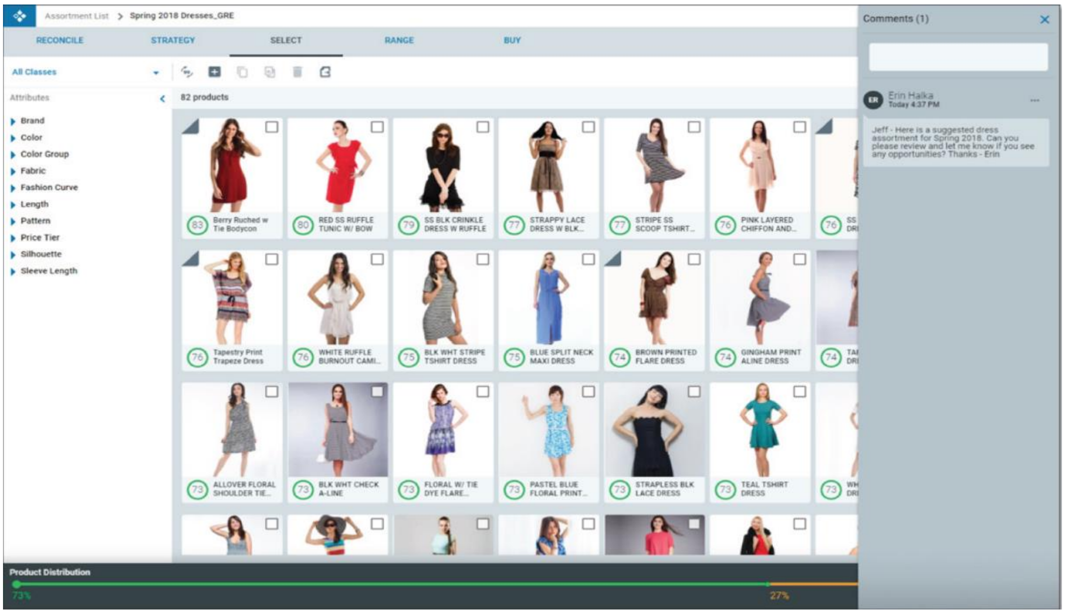

Figure 19: LuminateTM Personalized Assortment

4.2 JDA's Platform Architecture

Girish Rishi, CEO of JDA Software, at the annual "JDA Focus" conference in 2018 said that JDA's moonshot is too ambitious to build all by themselves.

Hence, JDA is working towards becoming a platform company, i.e. offering a complete set of APIs[3], development tools, and resources to enable an ecosystem of partners to integrate existing applications and build new applications and engines on top of the JDA's platform.

[3] In computer programming, an application programming interface (API) is a set of subroutine definitions, communication protocols, and tools for building software. In general terms, it is a set of clearly defined methods of communication among various components. A good API makes it easier to develop a computer program by providing all the building blocks, which are then put together by the programmer. (Wikipedia)

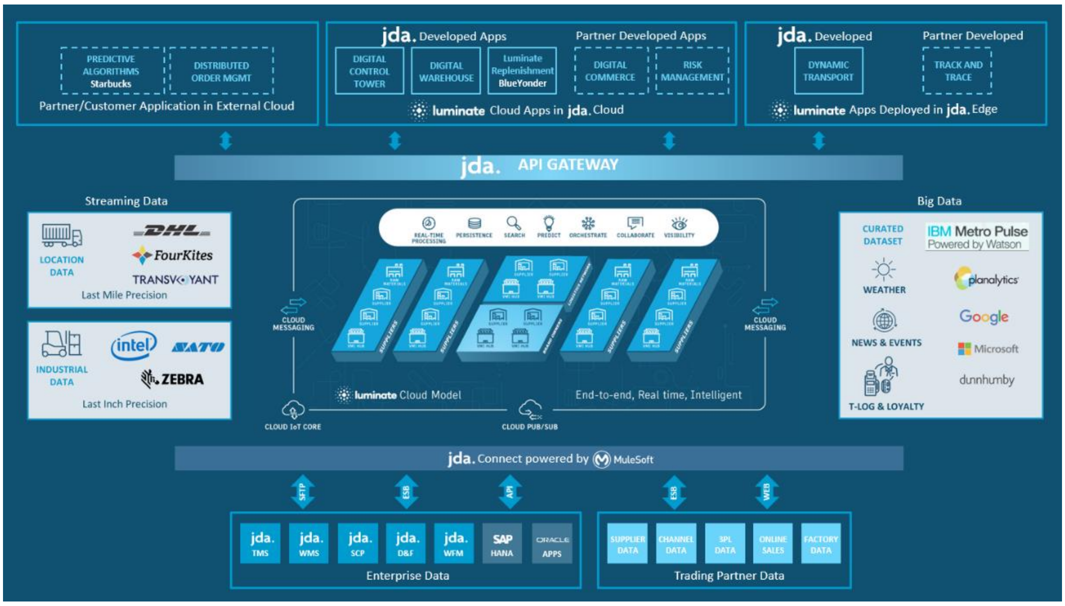

Figure 20: JDA Platform Architecture

In the center of *figure 20* there is a “data lake”, containing an end-to-end view of supply chain data from many different sources including:

- Enterprise data, both JDA and non-JDA applications (e.g. ERP);
- Trading partner data, such as channel partners, suppliers, customers, 3PL, etc.;
- Streaming data, IoT and GPS location data, such as vehicle locations, production status, etc.;
- Big Data, such as weather, news, transaction logs, loyalty, etc.

On top of this data lake, the JDA API Gateway[4] provides access to those combined data by JDA and partner applications in JDA cloud or third-party cloud, as well as by applications running on edge devices.

[4] An API gateway is the core of an API management solution. It acts as the single entryway into a system allowing multiple APIs or microservices to act cohesively and provide a uniform experience to the user. (Apigee)

4.3 JDA's Partner Ecosystem

JDA lately has increased even more its ecosystem of partners with some strategic acquisitions and partnerships to fuel its vision.

It built partnerships with best-in-class Big Data providers that feed *Luminate*™ portfolio: Planalytics and Dunnhumby for Retail and Planning; while FourKites and TransVoyant for Control Tower and Logistics.

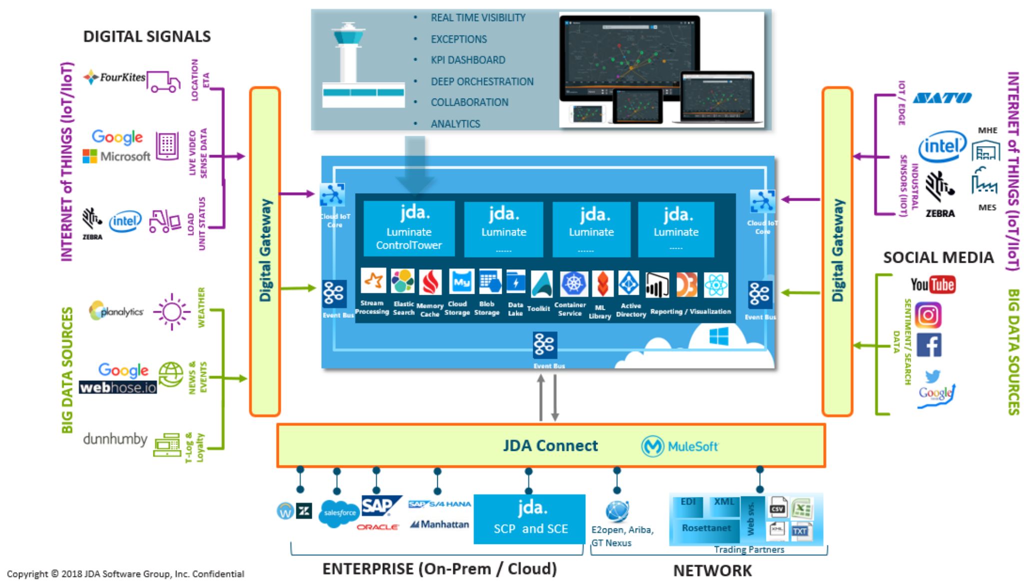

Figure 21: Ecosystem of data partners

FourKites offers a real-time supply chain visibility and predictive analytics platform for tracking shipment location and monitor load temperature in order to manage exceptions. It uses a proprietary predictive algorithm to calculate shipment arrival times, enabling customer to lower operating costs, improve on-time performance, and strengthen their end-customer relationships. With a network of more than four million GPS/ELD-connected devices, FourKites covers all modes, including ocean, retail, parcel, and over-the-road. (FourKites, 2018)

Smithfield, a meat-processing company, began tracking freight with FourKites software and improved on-time delivery rate from 87% to 94%. (Wall Street Journal, 8/29/2017)

Since 2012, **TransVoyant** has been collecting, cleansing, normalizing and storing massive real-time data streams from the global IoT, processing one trillion events per day: port congestion, road traffic, wave heights, customer clearance times, natural disasters, terrorism threats, labor strikes, social media and flight schedules. This allows to optimize inventory and order fulfillment based on dynamically calculated lead times, throughput, variability and causality. But, it allows also to source from low risk suppliers and select higher performing carriers. TransVoyant is helping companies to reach up to 20% improvement in OTIF (On Time In Full) orders, 30% reduction in buffer inventory, 5% increase in revenue, 20% reduction in transportation costs and 15-20% improvement in cash-to-cash. (TransVoyant, 2018)

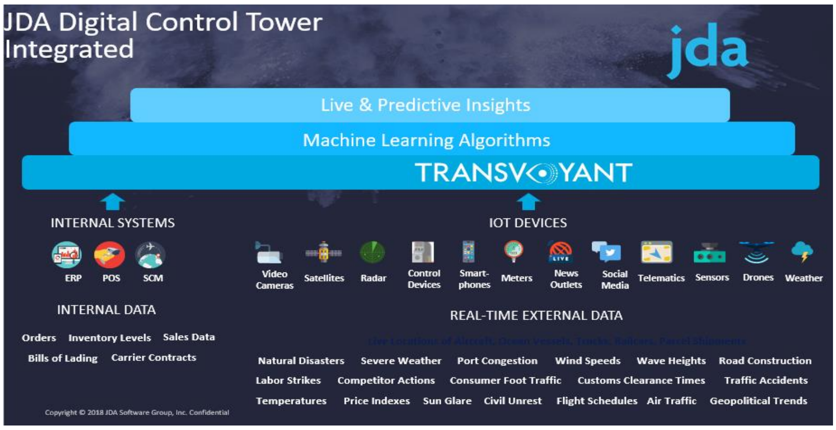

Figure 22: LuminateTM Control Tower Data Integration

Weather is one of the largest external variables impacting a consumer-focused business. **Planalytics** is the global leader in Business Weather Intelligence that helps companies measure and manage the impact of weather to their businesses, using weather as a metric in their everyday business practices.

Businesses typically gain 2-6% of incremental net income annually by removing weather-driven distortions from past sales.

Using "deweatherized" baselines, companies are able to improve the accuracy of their plans and reduce lost sales and inventory costs. (Planalytics, 2018)

Dunnhumby Customer Data Science Platform is a unique mix of technology, software and consulting that helps businesses deliver exceptional customer experiences, personalized to their needs and expectations, wherever they are: in-store, offline and online. (Dunnhumby, 2018)

JDA also started a partnership with **Microsoft Azure** (cloud platform) to fuel the SaaS solutions roadmap and accelerate the JDA's mission as the supply chain platform company. Victoria Brown, research manager, IDC said, "This partnership between established, trusted providers, uniting cloud services via Microsoft Azure, and supply chain via JDA addresses a gap in the supply chain ecosystem as cloud becomes a prerequisite for enterprises today as they embark on their digital supply chain transformations. Cloud-based supply chain deployments account for only about 40 percent of deployments today, and this new, trusted partnership could send that on an upward trajectory quite quickly."

In addition, JDA acquired **Blue Yonder** (BY) in 2018. It is a Germany company founded in 2008 by the CERN Prof. Dr. Michael Feindt. BY is recognized as the market leader in AI-ML solutions for retail and supply chain. Through BY proven data science capabilities, JDA will be able to fundamentally transform next-generation supply chains and retail merchandising operations.

4.4 Machine Learning Library

4.4.1 JDA's algorithms

JDA owns Labs in Canada which created a big library of different types of algorithms throughout the years of various innovation projects.

JDA has a variety of forecasting methods to suit different business scenarios, since one algorithm does not fit all.

The traditional algorithms can be classified as follows:

- Regression Based Algorithms:
  - > Fourier: it is a linear regression algorithm which assumes that demand and seasonality change at constant rate;
  - > Multiple Linear Regression (MLR): it assumes that stable demand is influenced by multiple external factors (casual variables such as weather, price, demographics, etc.);

- Smoothing Based Algorithms:
    - > Lewandowski: it assumes that highly non-stationary demand, seasonality and non-seasonality, change at inconstant rate due to demand-driven events;
    - > Holt-Winters: it is an exponential smoothing algorithm that is used when seasonality and demand are changing at different rates over time;
    - > Croston: it is an algorithm used for intermitted demand pattern of specific items (e.g. gears, engines, etc.);
    - > Moving Average: it is used for stable demand forecast based on recent past;
    - > AVS-Graves (JDA proprietary): it is used for intermittent demand patterns including seasonality;
- Other Proprietary Algorithms:
    - > Short Lifecycle (JDA proprietary): it is an attribute-based forecasting method which extracts and maps lifecycle curves, applies them to new forecasts and recalibrates as sales arrive;
    - > Profile Forecasting (JDA proprietary): it is profile-based forecasting algorithm that groups items with similar seasonal patterns, automatically identifying fast and slow movers and plying the right method to each to maximize accuracy.

Machine learning, data availability and public clouds have enabled a new frontier for cognitive demand forecasting.

Some ML algorithms experimented before Blue Yonder acquisition were:

- Supervised Learning algorithms, like Random Forest, Gradient Boosted Trees, Recurrent Neural Networks;
- Unsupervised Learning, such as K-means, DB-Scan, Hierarchical Clustering.

JDA Labs was able to reach 90% of automation and higher forecast accuracy using those advanced methods, but explainability of ML algorithm, data collection and data quality checking were still big issues. JDA addressed those problems through the acquisition of Blue Yonder company.

4.4.2 Blue Yonder's algorithms

BY owns two proprietary algorithms: NeuroBayes and Cyclic Boosting.

It is extremely fast in training algorithms since there is a huge team of PhD-level data scientists dedicated to this activity who know which data are needed for the algorithms, so the data collection process is faster.

ML algorithms are not one-size-fits-all business problems. BY spent 10 years working on the "Cyclic Boosting" algorithm focused on Retail, both brick-and-mortar and e-commerce, to help retailers avoid costly explosions in inventory and find the sweet spot for pricing products to move off the shelf.

This algorithm is a unique mix of different ML algorithms and it allows to reach 99% of automation and **higher explainability**, compared to traditional systems, since it takes into considerations up to **300 (internal and external) demand influencing** factors and shows their single **influences** on the forecast.

Those factors can be also **automatically linked together** to better understand their combined impacts on customer demand.

Figure 23:Some examples of demand influencing factors

For instance, the probability of having a barbeque on a sunny day is higher than the one on a rainy day. Therefore, the quantity of meat sold on a sunny Saturday with 25 degrees is different from the one sold on a Saturday with 25 degree and 50% probability of rain.

BY offers two types of solutions with different capabilities: Demand Forecast and Replenishment; and Price Optimization.

4.4.2.1 How does Demand Forecast & Replenishment work?

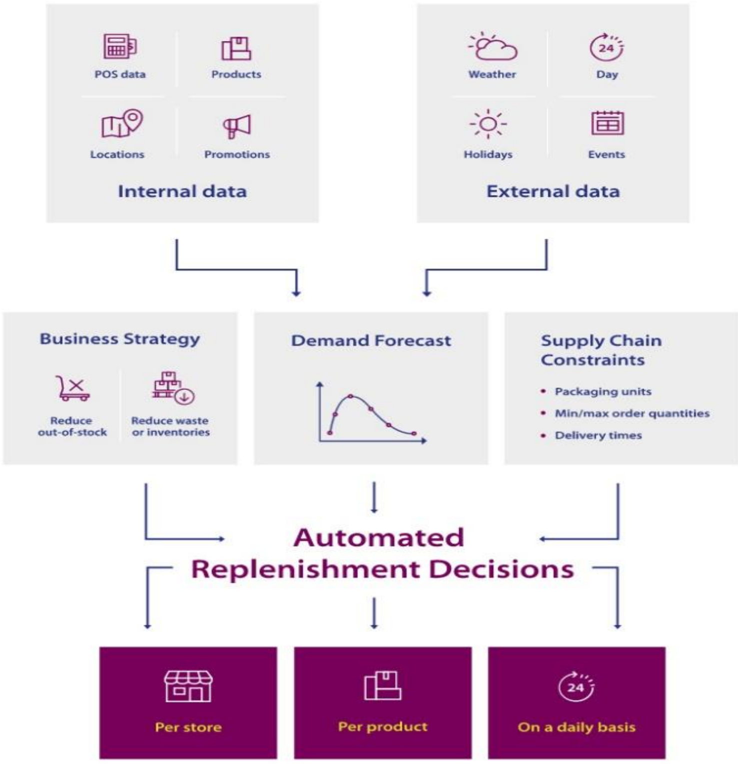

Figure 24: Demand Forecast & Replenishment process

- Determining the demand forecast:

An important differentiator of Demand Forecast and Replenishment solution is the **level of granularity** supporting the order recommendation.

Traditional approaches predict weekly demands, BY approach delivers daily recommendations per SKU (Stock Keeping Unit), per store without the need of unnecessary manual intervention. BY provides the calculated forecast as a **detailed probability density function**, instead of “point projections”.

Order forecasts are made daily for up 21 days in the future. This frees up retailers' time to deliver their brand promise and meet changing customer expectations.

- Strategic and operational alignment:

The calculation is optimized to meet strategic KPI's (e.g. out-of-stock, waste or inventories), but also retailer's margin and revenue expectations. Constraints are also considered such as considerations of stock levels, deliveries already scheduled, packaging and minimum order quantities.

- Determining optimized decisions:

Recommended order quantities are generated for thousands of products in hundreds of stores, every day. This best balance ordering algorithm allows the replenishment to run with the highest degree of automation (unbiased decisions) possible with self-adjusting updates with new data.

Retailers can reach up to 80% out-of-stock reductions, 10 times increased product availability and 50 times fewer manual interventions.

To illustrate, on *figure* 25, the histogram shows the demand probability for a specific SKU-store-date combination. For instance, apples in store #230 on June 20th. The vertical bars show that stocking 4 apples in that store on that day will be probably enough to meet demand, the store will likely sell most or all of them, so the risk of stock-out is small. But if a customer wants to buy a fifth apple or more, the store would lose out on revenue. The green curve on *figure 25* represents the expected value of costs for each stock level, considering potential loss of revenue due to out-of-stock as well as potential markdowns and waste.

In this case, the algorithm identifies a stock level of 9 units as optimal.

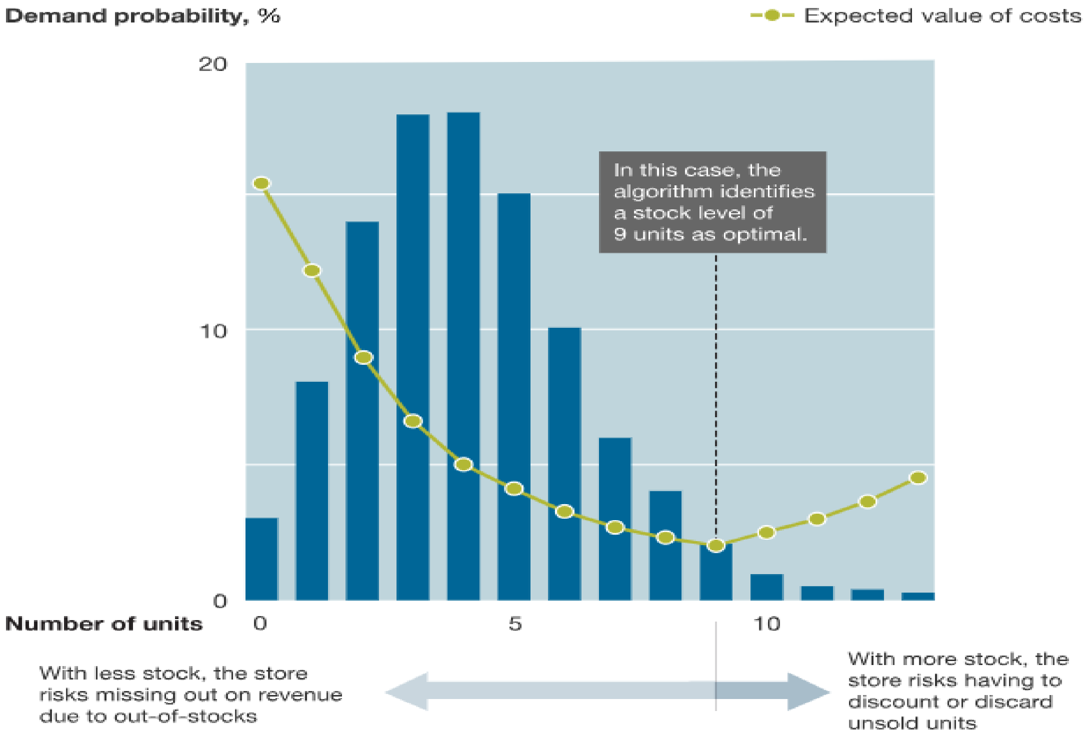

Figure 25: An example of Demand Forecast & Replenishment

For example, the grocer company Morrisons implemented Blue Yonder's Replenishment Optimization platform for nearly 500 stores. That meant automating about 13 million ordering decisions, which reduced shelf gaps by 30 percent while reducing of 2-3 days the stock holding in-stores.

4.4.2.2 How does Price Optimization work?

For retailers, being able to implement strategic pricing techniques is key to sustainable growth. BY Price Optimization solution optimizes prices for every channel and every product according to consumer demand, brand loyalty and competitive advantage. The solution learns the relationship between price changes and demand while incorporating a retailer's business strategy. It also provides a measurable impact on revenues and return on investment.

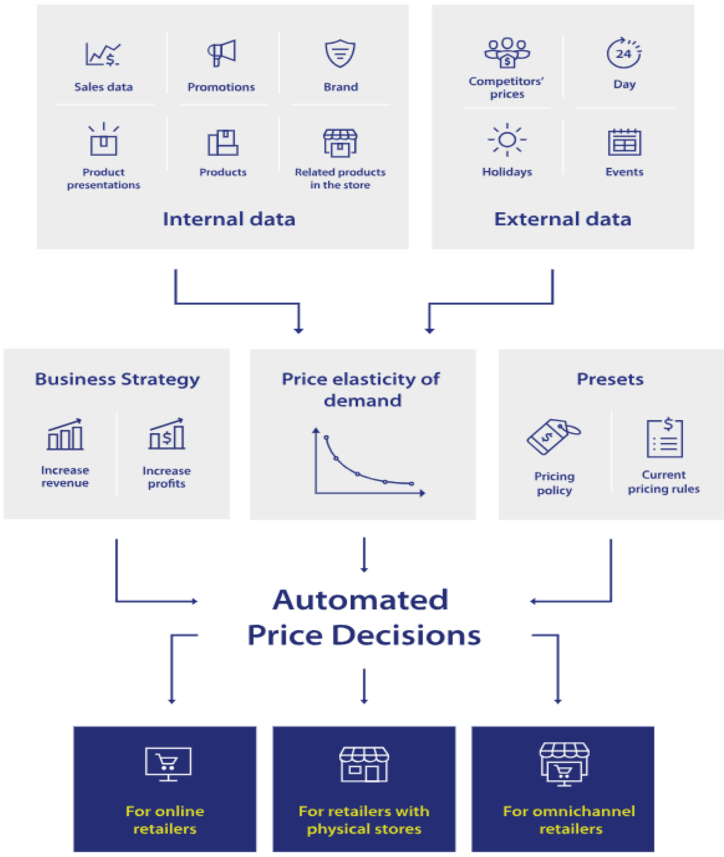

Figure 26: Price Optimization Process

- Daily calculation of optimized prices:

This solution analyses historical and current data that considers strategic goals, pricing policy, current pricing rules, sales history, external factors, and product-related ones, such as product life cycle. Then, **individual price-demand elasticities** are determined and integrated, with a continuous optimization and testing using KPI-driven cost functions.

- Determining optimizing decisions:

Automated delivery of price decisions at a granular level is done with continual self-adjustment via regular updates.

For instance, if a small price reduction leads to a significant increase in sales volume, the system would recommend larger order quantities. On the other hand, if demand for a product does not change much, even if it was sold at a deep discount, the system would recommend smaller order quantities to minimize losses due to markdown.

Retailers can reach up to 15% increase in revenue, 5% improvement in profit and 20% reduction in stock levels.

Of course, companies with a big business case which are interested in implementing these new JDA and BY advanced solutions, firstly, need to check their actual capabilities and readiness to digital innovation.

5 Digital Supply Chain Maturity Model

5.1 Literature Review

Maturity is defined as a specific process for explicitly defining, managing, measurement and control of the evolutionary growth of an entity. (Paulk, 1993)

In other words, maturity implies an evolutionary progress of an entity from an initial to a desired or occurring final stage. Before reaching the end stage, different maturity levels (stages of growth) need to be experienced.

A maturity model is a tool used to evaluate the maturity capabilities of some elements and identify the appropriate actions to reach a higher level of maturity. (Kohlegger, 2009)

In literature there are three types of maturity models differentiated by their purposes (De Carolis, 2017):

- Descriptive purpose: models which assess the as-is situation of the organization or process;
- Prescriptive purpose: models which indicate how to approach maturity improvements to positively affect business value;

- Comparative purpose: models which allow benchmarking across companies (e.g. compare similar practices across organizations to benchmark maturity within different industries).

Digitalization triggers a lot of new possibilities for innovation and improvements of companies, but obtainable opportunities differ depending on the actual maturity level of a company's capabilities.

Before starting the transformation process, companies should:

- Define a vision aligned with strategic goals;
- Then, they should undertake a comprehensive digital maturity assessment, engaging different stakeholders (i.e. C-level managers, consultancy partners, etc.) to obtain more realistic results about the current business and technical capabilities;
- Once firms have a clear view of their current level of digital readiness, they should perform a root-causes analysis to identify problems and prioritize potential changes based on the expected value. Hence, companies have to explore which digital opportunities match their needs and capabilities;
- Afterward, a multiyear transformational roadmap should be defined to guide them properly towards digitalization.

Even though such methodologies are emerging, no digital maturity model is established yet.

During my internship experience in JDA's Strategic Services team, after having performed some research, either online and in literature, to the best of the knowledge reached, many maturity models have been identified related to Supply Chain in Industry 4.0, some of them are listed in the *figure 27*.

MODEL NAME	DELIVERED BY	DOMAIN
CPS Maturity Model	RWTH Aachen University	Cyber-Physical System
Digital Readiness Assessment Maturity Model (DREAMY)	Politecnico di Milano	Manufacturing companies
Smart Manufacturing Readiness Level (SMSRL)	NIST (National Institute of Standards and Technology)	Manufacturing companies
Manufacturing Operations Management (MOM)	MESA (Manufacturing Enterprise System Association)	Manufacturing companies
An Industry 4 readiness assessment tool	The University of Warwick	Industry 4.0
The connected Enterprise Maturity Model	Rockwell Automation	Industry (OT/IT Networks)
IMPULS-Industry 4.0 Readiness	VDMA, RWTH Aachen	Industry 4.0
Industry 4.0 readiness and maturity model	Fraunhofer Austria	Industry 4.0, manufacturing
Digital Supply Chain Compass	McKinsey & Company	Supply Chain
Digital Acceleration Index	Boston Consulting Group	Supply Chain
Demand-Driven Model for Supply Chain Maturity	Gartner	Supply Chain
Digital Maturity Model	Deloitte+tmForum	CPSs (communication service providers)
3DP (3D Printing) Maturity Model	EY	Additive Manufacturing
Industry 4.0/Digital Operations self-assessment	PwC	Industry 4.0
The Digital Maturity Model 4.0	Forrester	eBusiness and Channel strategy

Figure 27: Supply chain maturity model related to Industry 4.0

After having compared and evaluated the most relevant ones, my internship purpose was to create a comprehensive digital supply chain maturity model to assess manufacturing and retail company's readiness level to start the digital transformation journey through the implementation of *Luminate™* digital solutions.

In the next sections, I will analyze and compare three models proposed online by three consulting and research companies (McKinsey, Boston Consulting Group, and Gartner) to show how JDA's Strategic Services team can differentiate from them with a new digital maturity model offering.

5.1.1 Mckinsey & Company's Model

According to McKinsey's vision of the future state, Supply Chain 4.0 will be faster, more flexible, more granular, more accurate, and more efficient.

Those characteristics are enabled respectively by:

- Advanced forecasting approaches which leads to time reduction;
- Ad-hoc and real time planning which allows a flexible reaction to changing solutions;
- Micro segmentation and mass customization trends;
- Next generation of performance management systems which provide real-time, end-to-end transparency through the supply chain;
- Automation that boosts efficiency.

As a supply chain grows along the 4.0 digital journey, it encounters different archetypes of supply chain maturity (Alicke, 2016):

- Supply Chain 2.0: “mainly paper-based” SCs with a low level of digitization, where most of the processes are executed manually. The digital capabilities of the organization are very limited and available data is not leveraged to improve business decisions;
- Supply Chain 3.0: SCs with basic digital components in place. IT systems are implemented and leveraged, but digital capabilities still need to be developed. Only basic algorithms are used for planning/forecasting and only few data scientists are part of the organization to improve its digital maturity;
- Supply Chain 4.0: SCs in the highest maturity level that leverage all data available for improved, faster, and more granular support of decision making. Advanced algorithms are leveraged, and a broad team of data scientists works within the organization, following a clear development path towards digital mastery.

Industry 4.0 wave improves four main SCM levers: service, capital, cost, and agility.

In “McKinsey Digital Supply Chain Compass” these improvement levers are structured and mapped into six main value drivers:

- Planning;
- Physical Flow;

- Performance Management;
- Order Management;
- Collaboration;
- Supply Chain Strategy.

Every value driver has its own improvement enablers, represented along the edges of the pie chart in *figure 28*.

Figure 28: McKinsey Digital Supply Chain Compass

Mckinsey developed a diagnostic tool to assess the supply chain along five maturity levels (where stage 1 means no maturity and stage 5 means very high maturity), and five dimensions (*figure 29*):

- Data;
- Analytics;
- Software/Hardware;
- People;
- Process.

Very high maturity | High maturity | Medium maturity | Low maturity | No maturity | x Score

	SC strategy		Planning					Physical flow					
	Network design	SC segmentation	Demand planning	Inventory mgmt	S&OP/ integrated business planning	Master planning	Scheduling	Warehouse operation	Transport operation	Assessment and tender of logistics	Order mgmt	Collaboration	Performance mgmt
Data	1	1	1	2	1	1	4	5	1	5	2	1	1
Analytics	3	1	2	1	5	4	1	1	3	3	1	4	3
Software/ hardware	4	1	5	1	1	3	3	2	1	2	1	3	4
People	1	1	1	2	1	1	4	5	1	4	2	1	1
Process	3	1	2	1	5	4	1	1	3	3	1	4	3

Enablers: SC organization, mindset and capabilities, SC IT

Figure 29: A maturity assessment along the major SC 4.0 dimensions

The McKinsey's Assessment helps companies understand the current digital maturity of the organization and what is required to reach the next performance level leveraging 4.0 tools to shape the roadmap for digitization and estimate the potential impact.

From my personal standpoint, McKinsey's assessment lacks an in-depth analysis of the five dimensions; change management, talent management and acquisition, digital workplace and the use of agile methodology are oversighted.

5.1.2 Boston Consulting Group's Model

From BCG's perspective, DSC are not new; since companies have been using them to improve service and reduce cost. But the explosion of large availability of data and new digital technologies has allowed the emergence of the supply chain of the future.

The BCG's Digital Acceleration Index (DAI) helps organizations assess their digital maturity, identify strengths and weaknesses, and evaluate how well they digital perform against peers in order to develop an integrated roadmap for reaching the targeted digital state. (Grebe, 2018)

DAI is based on four building blocks (*figure 31*):

- Business strategy driven by digital;
- Digitize the core;
- New digital growth;
- Enablers.

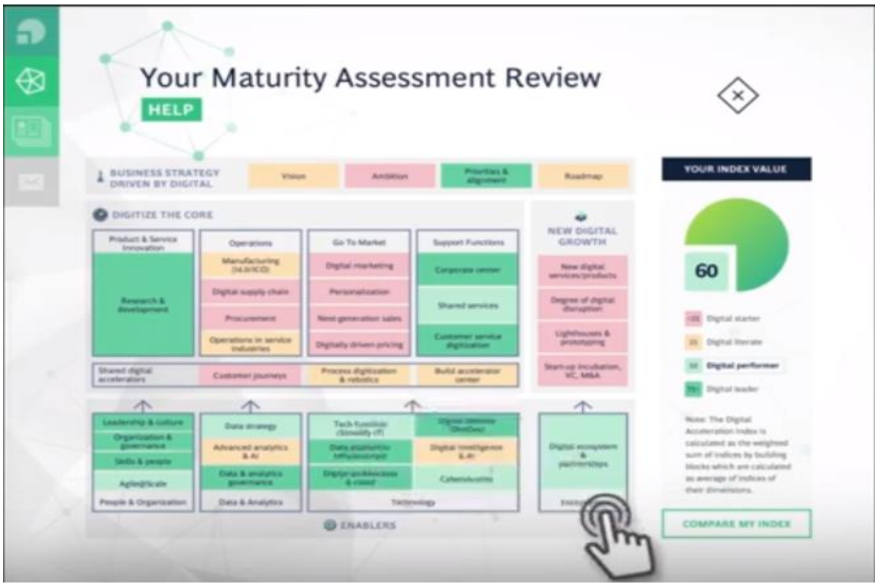

Figure 30: Overview of building blocks and subdimensions of DAI

Related areas and dimensions of the building blocks are listed in the *figure 31*:

BUILDING BLOCKS	AREAS	DIMENSIONS
Business strategy driven by digital	• Vision; • Ambition; • Priorities & Alignment; • Roadmap.	-
Digitize the core	• Product and Service Innovation	• R & D
	• Operations	• Manufacturing; • Digital Supply Chain; • Procurement; • Operations in service industries.
	• Go to Market	• Digital Marketing; • Personalization; • Next-Generation sales; • Digitally driven pricing.
	• Support Function	• Corporate center; • Shared services; • Customer Service Digitization.
New Digital Growth	• New digital services/products; • Degree of digital disruptions; • Lighthouses & prototyping; • Start-up incubation, VC, M&A.	-
Enablers	• People & Organization	• Leadership & Culture; • Organization & Governance; • Skills & People; • Agile & Scale.
	• Data & Analytics	• Data Strategy; • Advanced Analytics & AI; • Data & Analytics Governance.
	• Technology	• Tech functionality; • Data Platform Infrastructure; • Digital Architecture; • Digital Delivery (DevOps); • Digital Intelligence; • Cybersecurity.
	• Ecosystem	• Digital Ecosystem & Partnership

Figure 31: Areas and Dimensions of DAI

Responses to the questionnaire determines the company's index value. It is calculated as a weighted sum of indices by building blocks, which are calculated as average of indices of their dimensions.

The final DAI indicates the overall digital maturity in the organization and helps determine in which of the four stages a company has achieved for each dimensions and activity:

- Digital Passive (Index < 25): it is the first stage of digital maturity where the company has not yet defined its target digital state for technologies and the overall organization. Business and IT functions sometimes collaborate on digital topics based on ad-hoc demand, but these two functions are aligned just when digital projects are executed jointly;
- Digital Literate (25<Index<50): organizations start recognizing the need for digital investments and try to define a roadmap. In this second stage, digitization of the process begins as well as digital initiatives executed in functional silos by business units, functions and regions;
- Digital Performer (50<Index<75): digital is managed in an integrated way, business and IT functions are aligned and successful digital initiatives start to be commercialized, and some disrupting businesses are launched;
- Digital Leader (Index>75): digital is a key driver of the company's value, therefore it is embedded throughout the entire company. Digital strategy and roadmap are well defined, and digital initiatives add clear value and contribute to improve strategy.

From my perspective, this model lacks supply chain process-focused analysis, performance management, change management, digital workplace and talent management and acquisition.

5.1.3 Gartner's Model

"The emerging Digital Supply Chain is an intelligent and dynamic organism that orchestrates the delivery of customer solutions across a digitally connected partner ecosystem" is the definition of DSC given by Gartner. (Aykens, 2018)

Gartner's demand-driven model for supply chain maturity is used to engage stakeholders in an evaluation of current maturity and discussion for the case for change. The results help identifying improvement opportunities, change strategies for more comprehensive upgrades to capability, and transformation roadmap. (Lord, 2017)

The five stages of supply chain maturity that can be identified are summarized in *figure 32*:

React	Anticipate	Integrate	Collaborate	Orchestrate
• Revenue focus • Siloed execution	• Standard, scalable functional processes • Competing goals & metrics	• Cross-functional trade-offs and singular value chain goals	• Extended networks • Outside-in mindset • Tailored outcomes	• Multienterprise ecosystem • Custom solutions, shared joint value

Figure 32: The five stages of Supply Chain Maturity

The seven supply chain dimensions taken into considerations are depicted in *figure 33*:

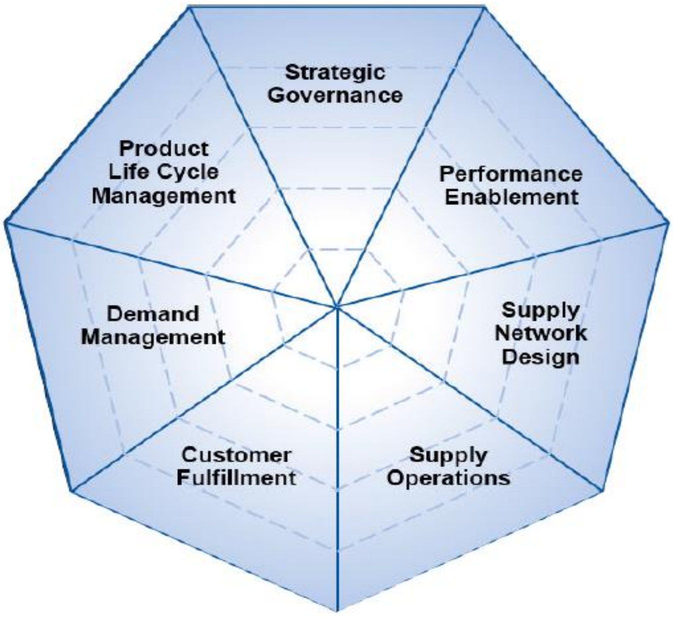

Figure 33: The Seven Dimensions of Demand-Driven Supply Chain

In *figure 34* the subdimensions are described.

DIMENSIONS	SUBDIMENSIONS
1. Strategic Governance	• Scope and Focus; • Goal Orientation; • Strategy Development; • Corporate Social Responsibility; • Integrated Business Planning.
2. Performance Enablement	• Scope and Focus; • SC Risk Management; • Innovation Management; • Talent; • IT Enablement.
3. Product Life Cycle Management (PLM)	• Scope and Focus; • Design and Launch; • Life Cycle Value Assessment; • Technology • Metrics.

4. Supply Network Design	• Scope and Focus; • Design Methods; • Product Supply Network; • Product Distribution Network.
5. Supply Operations	• Scope and Focus; • Supply Planning; • Supplier Management; • Production and Logistics Operations; • Technology • Metrics.
6. Demand Management	• Scope and Focus; • Planning; • Sensing and Shaping; • Technology; • Metrics.
7. Customer Fulfillment	• Scope and Focus; • Order to Cash; • Delivery; • Technology; • Metrics.

Figure 34: Dimensions and related sub-dimensions

According to this model, during these five stages of maturity, organizations increasingly adopt an "outside-in" mindset, integrating business unit supply chain functions, customers and networks, benefiting from increasing levels of standardization, scalability and adaptability. By delivering more efficient and better quality service to customers even as demand and supply factors fluctuate, they maximize profitability.

Process-focused analysis across the core dimensions should be considered a crucial step before implementing a new digital solution and, in my judgment, this model also lacks this in-depth analysis (mainly around Data). Change management, agile methodology, digital change and digital workplace are also undervalued.

5.1.4 Models Comparison

ELEMENT:	**COMPANIES:**		
	McKinsey	**BCG**	**Gartner**
Model Name	Digital Supply Chain Compass	Digital Acceleration Index (DAI)	Demand-Driven Model for Supply Chain Maturity
Model Purpose	Descriptive and Predictive	Descriptive, Predictive, and Comparative	Descriptive and Predictive
Objectives	1.to help companies understand the current digital maturity of the organization; 2. to identify tools and opportunities to shape the road map for digitization; 3. to estimate potential impact of digital transformation.	1.to assess organization digital maturity; 2. to uncover strengths and weaknesses and related opportunities; 3. to benchmark digital performance to shape a roadmap for transformation.	1. to evaluate the current maturity and discuss of the case for change; 2. to identify improvement opportunities and develop change strategies; 3. to develop a transformation roadmap.
Focus	SC Enterprise level	SC enterprise level	SC enterprise level
Target Group	C-level executives	C-level executives	C-level executives
Analysis Dimensions	1. Data; 2. Analytics; 3. Software/Hardware; 4. People; 5. Process.	1. People and Organization; 2. Data and Analytics; 3. Technology; 4. Ecosystem.	differ depending on the supply chain capability considered.
Maturity Levels	5	4	5
Gap:	• Supply chain process-focused analysis across dimensions; • Change Management: • Agile methodology; • Digital Workplace; • Talent Management and acquisition.	• Supply chain process-focused analysis across dimensions; • Change Management: • Digital workplace; • Talent Management and acquisition; • Performance management.	• Supply chain process-focused analysis across dimensions; • Change Management: • Agile methodology; • Digital workplace; • Digital change.

Figure 35: Models Comparison

5.1.5 Models Gap Analysis

In a nutshell, during the gap analysis of existing maturity models, the following difficulties have been identified:

- Supply Chain Maturity Model are mainly focused on enterprise strategic level of companies. Single process-focused assessment for all the supply chain processes along the core dimensions has been overlooked;
- Current models present superficial approaches to data and technology, which are the core components of 4.0 companies;
- Change Management, Agile Methodology and Digital Change have been undervalued;
- Current models do not relate to the technologies from Industry 3.0 which are still and will be the core part of companies; therefore, a combination of core technologies should be used;
- Current maturity models do not refer to the maturity of assessed technologies, leading to the risk of underestimation of CAPEX (Capital Expenditure), TCO (Total Cost of Ownership), applicability and reliability of the technologies;
- Current models are focused in the majority on top (C-level) managers, which is important to start the Industry 4.0 initiative, but the involvement of the middle management is a crucial aspect in a successful implementation of the strategy.

This gap analysis may contain some faults, due to the lack of accessibility to the detailed descriptions of the models and intellectual property issues; since consulting companies, which provide the service of digital maturity assessment to organizations, restrict access to their intellectual property.

However, this gap analysis provides the basis for the development of a more comprehensive digital supply chain maturity model offering.

5.2 Maturity Model Offering for JDA Software

Being able to successfully implement JDA's solutions requires an in-depth analysis of available and required capabilities. This is the reason why I decided to develop two comprehensive Digital Supply Chain Maturity Models for JDA's Strategic Services team:

- Enterprise Digital Maturity Model (EDMM);
- Process-focused Digital Maturity Model (PDMM).

PDMM is what makes JDA differ from other companies' models.

5.2.1 Enterprise Digital Maturity Model

JDA's Strategic Services team can offer EDMM as a teaser to attract new customers for core solutions and *Luminate*^{TM} advanced solutions or to increase the engagement of mature existing customer for the implementation of *Luminate*^{TM}.

This model helps:

- to assess the current supply chain maturity of the customer;
- to understand the customer's readiness for digital initiatives;

- to identify digital transformation opportunities with JDA's solutions.

Four increasing stages of digital maturity are identified (*figure 36*):

- Reactive;
- Anticipate;
- Proactive,
- Autonomous.

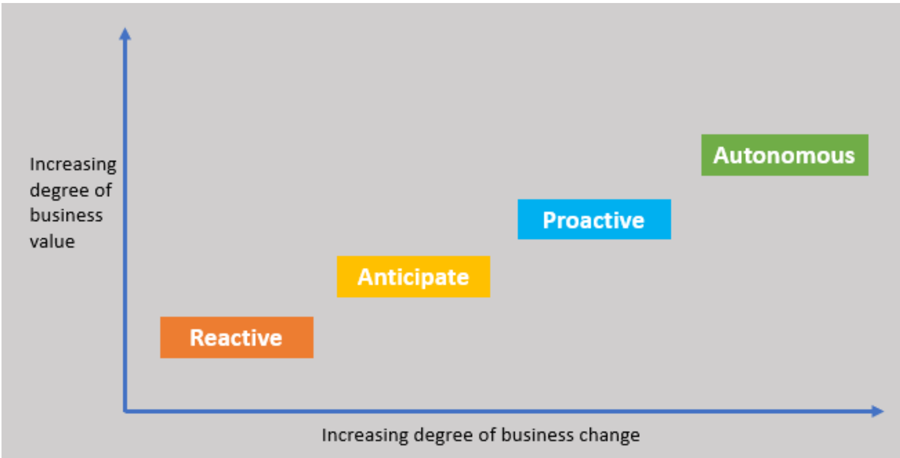

Figure 36: Four increasing stages of digital supply chain maturity

The six core analysis areas are defined "perspectives" (*figure 37*):

- **People**: how roles and responsibility are defined, the executive support, how employees are encouraged;
- **Process**: the way in which the processes are carried out, monitored and controlled;
- **Data Core:** the strategy, quality and availability of the data needed;
- **Technology**: the availability and suitability of underlying technology platforms, programs and systems that support the other pillars;

- **Digital Change**: the organization's culture, including the willingness to invest on the necessary digital initiatives, training, the attention to manage change, especially staff roles;
- **Agile Project Management (PM)**: the company's use of agile approach during project and the availability of resources for the Agile team.

An assessment is conducted along the perspectives by the client and JDA business consultant. The result of the assessment characterizes and positions the perspectives in the four levels of maturity represented by different degrees of business value created by the supply chain, and different levels of business change needed to get there.

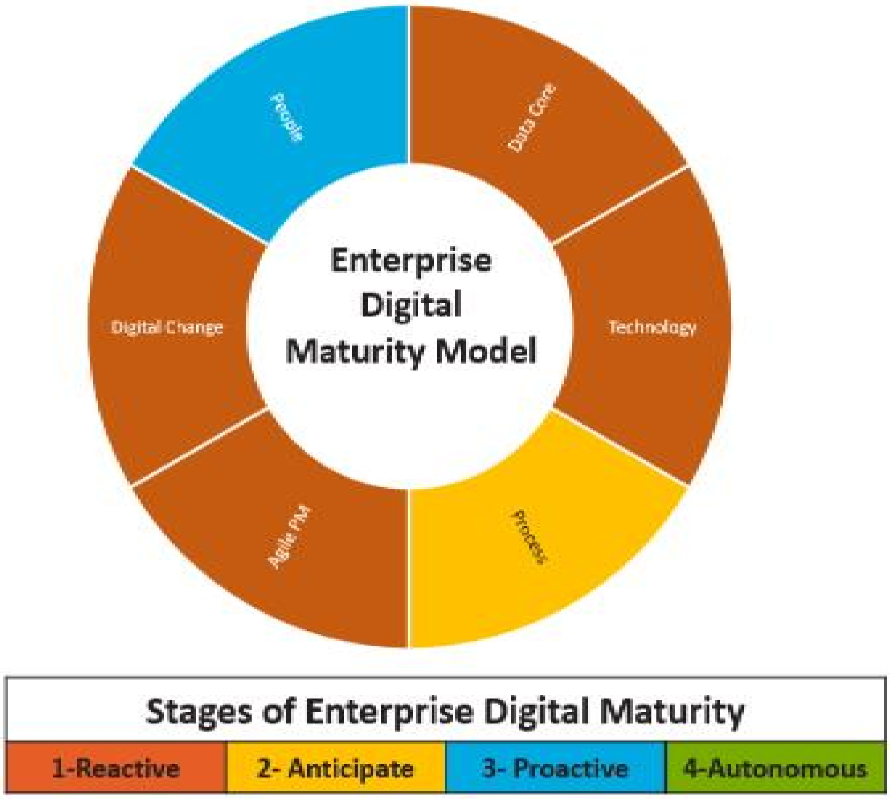

Figure 37: EDMM: perspectives and maturity levels

The **targeted groups** of stakeholders for this model are C-level executives, since it is not an in-depth specific process analysis and all the perspectives are analyzed considering the enterprise.

The result of the questionnaire is analyzed by the Strategic Services team and the **outcomes** of this assessment would be a list with “observations” and “digital transformation tips” regarding every area, and a risk mitigation plan is proposed to address every issues and boost improvements.

An example of the outputs is depicted in *figure 38* and *figure 39*.

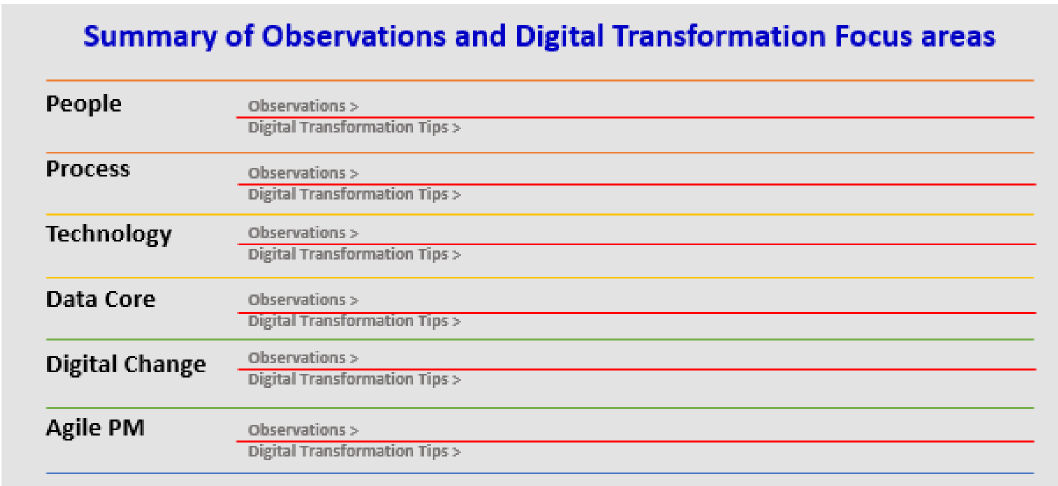

Figure 38: Summary of Observations and Digital Transformation Tips

In “Observations” the description of the characteristics of every perspective is outlined according to the organization maturity level identified. Then, an overall percentage score for each perspective is assigned.

Every perspective can be in different stages of digital maturity.

While "Digital Transformation tips" contains recommendations regarding which digital initiatives should be embraced in each perspective in order to shift to the next levels based on the Observations results.

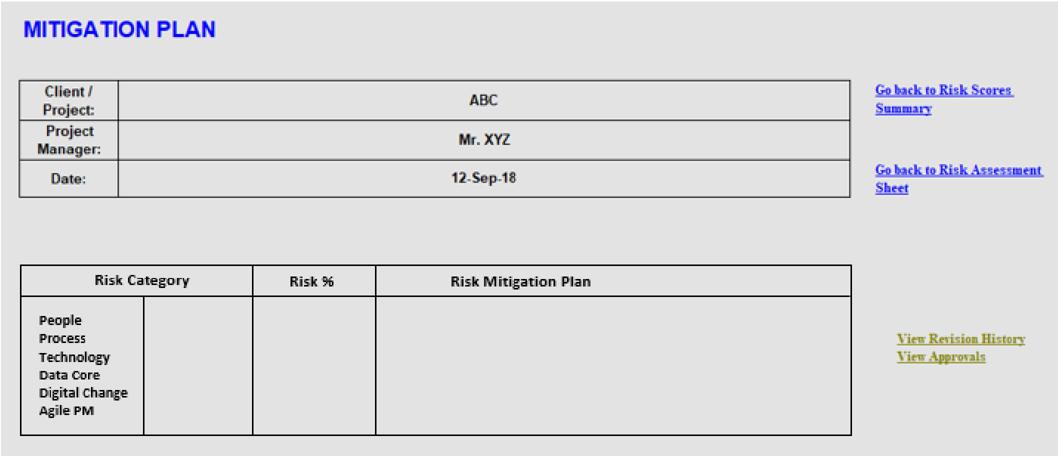

Figure 39: Mitigation Plan

5.2.2 Processed-focused Digital Maturity Model

PDMM is an in-depth analysis of different supply chain end-to-end processes, with a special focus also on data, analytics and technology. It allows to obtain the real current digital maturity level and capabilities in order to create a realistic transformation roadmap towards the next maturity level through the implementation of JDA's software and cloud-based solutions.

Therefore, in the **targeted group** middle management is included.

The PDMM helps:

- To assess the current supply chain maturity of the customer;
- To understand the customer's readiness for digital initiatives;
- To identify digital transformation opportunities with JDA's solutions;

- To recommend how to get to a desired maturity stage through an agile transformation roadmap.

The four increasing stages of digital maturity are the same as EDMM:

- Reactive;
- Anticipate;
- Proactive;
- Autonomous.

In this model, the considered **Process** will be a perspective, but also the main **subject of the assessment**.

Some of the main processes for which JDA can develop assessments and provide solutions may be:

- Demand Planning;
- Supply Planning;
- Inventory Optimization;
- Integrated Business Planning;
- Sourcing and Procurement;
- Manufacturing, Planning and Scheduling;
- Execution and Fulfillment.

In the same way of the EDMM, an assessment is performed, and the results of this questionnaire are analyzed by the Strategic Services team.

The **main outcomes** of this PDMM will be:

- Company’s specific process digital maturity assessment;
- Digital Vision Outline (*figure 40*);
- Digital Initiatives Summary (*figure 41*);
- Data Readiness Check (*figure 42*);
- Digital Agile Roadmap (*figure 43*).

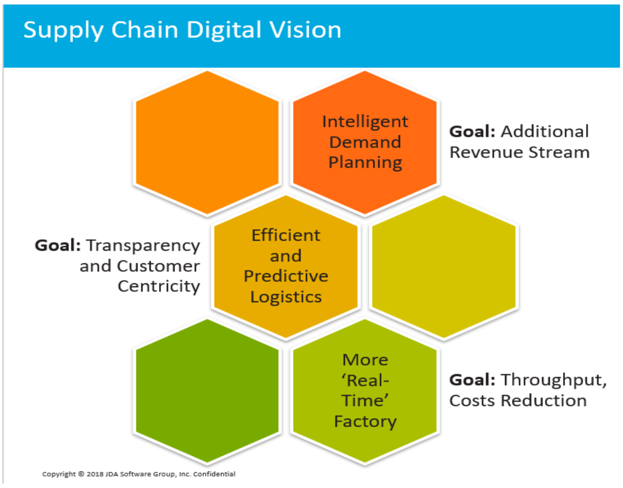

Figure 40: Example of Digital Vision Outline

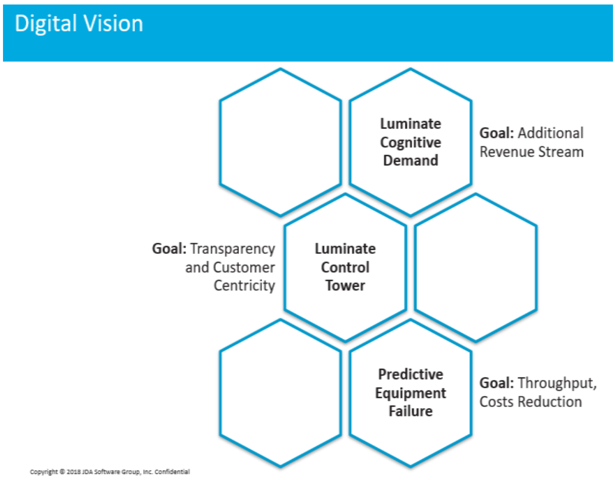

Figure 41: Example of Digital Initiatives Summary

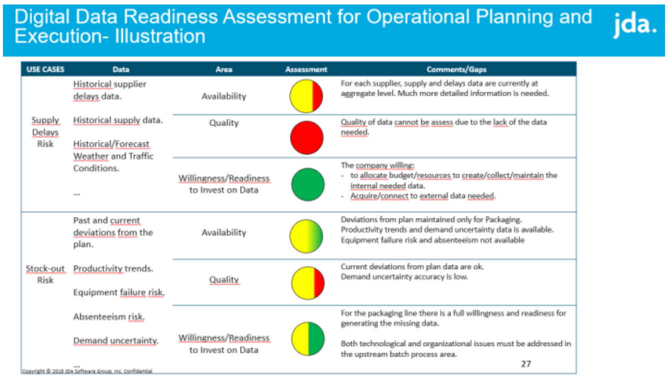

Figure 42: Example of Data Readiness Check

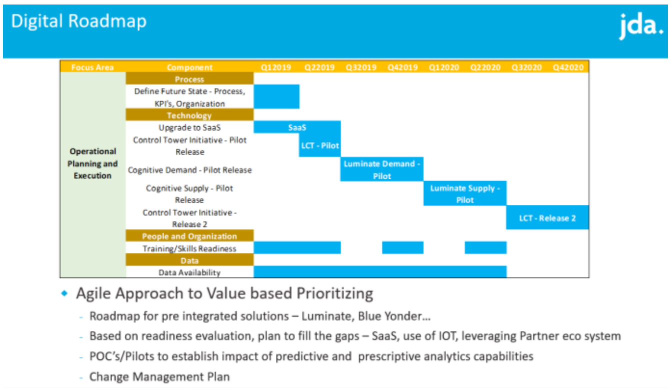

Figure 43: Example of Digital Agile Roadmap

The main perspectives are split in sub-areas denoted as "Focus Areas", which are (*figure 44*):

1. **People**

   - **Digital Leadership and Vision**: the degree of sponsorship and involvement of C-level executives and how much digital vision is defined, understood and used to capture value;
   - **Organization Design**: it refers to how roles and accountability of activities are defined and the level of cross-functional collaboration;

- **Talent Management and Acquisition**: it is the management, attraction, hiring and integration of new employees to the SC organization and the process by which existing employees take on and excel in new roles;
- **Incentivizing and Rewarding Behaviors**: it is the process by which most companies' HR (Human Resource) departments measure and reward an individual's contribution to the business over time.

2. **Process** (a specific one)

- **Digital Use Cases**: how processes are carried out in specific cases;
- **Ecosystem Collaboration**: the degree of internal and external collaboration, partnerships, and how enterprise leverages its ecosystem.

3. **Data Core**

- **Availability**: the ability to ensure that required data is always accessible;
- **Quality**: the degree of accuracy, completeness, reliability, relevance and validity of the required data;
- **Willingness to Invest**: the degree of willingness to collect, generate, access and acquire the necessary (new) data;
- **Strategy and Governance**: the strategy and management of the availability, usability, integrity and security of data used in the enterprise;

- **Data and Analytics Platforms**: the availability of integrated and complete solutions for managing and generating data.

4. **Analytics:** how much Advanced Analytics is used to create value
   - **Descriptive:** “What has happened?”;
   - **Diagnostic/Explanatory**: “Why has happened?”;
   - **Predictive**: “What could happen?”;
   - **Prescriptive**: “What should we do”.

5. **Technology**
   - **Process Enabling Solutions**: the degree of availability of the required technological solutions;
   - **Ecosystem Connectivity**: how well technological assets are integrated into business processes across enterprise.

6. **Digital Change**
   - **Adaptive Learning**: the methods, contents by which associates' skills, knowledge, behaviors and experience are improved, changed and expanded;
   - **Digital Workplace**: the business strategy used to boost workforce dexterity through and engaging and intuitive work environment:
   - **Culture and Shaping Behaviors**: the degree of openness towards changes and innovation, including also innovation with outside partners;

- **Change Leadership Strategy**: how digital opportunities are exploited for new business value.

7. **Agile Project Management**
    - **Core Team Competencies** (Business, Data Science, IT): the skills, knowledge, behavior and experiences that an individual should have to be successful at a specific role at different levels;
    - **Readiness**: the degree of readiness to use an agile approach.

Metrics are assessed around every Perspectives through:

- **Insights**: how change effectiveness is monitored and how individual's contribution is measured;
- **KPIs**: which key performance indicators are measured and how results are analyzed.

The maturity level of a perspective considers the level of its Focus Areas.

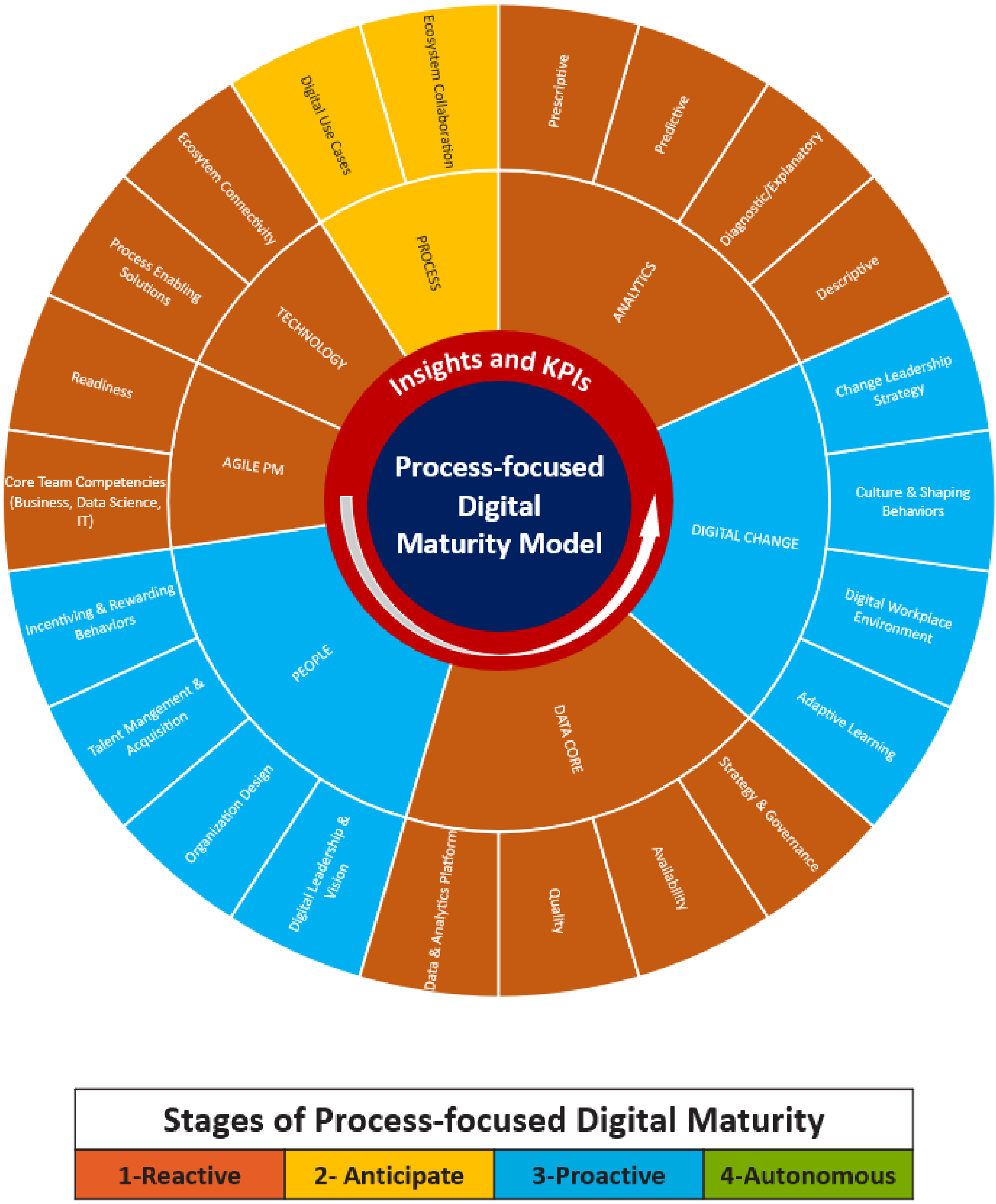

Figure 44: Process-focused Digital Maturity Model

5.2.3 Commonalities and Differences

Differences and similarities of both models are described in the *figure 45*:

ELEMENTS	DIGITAL SUPPLY CHAIN MATURITY MODELS	
Model Name	ENTERPRISE DIGITAL MATURITY MODELS (EDMM)	PROCESS-FOCUSED DIGITAL MATURITY MODELS (PDMM)
Objectives	• to assess the supply chain digital maturity of the client; • to understand the customer's readiness for digital initiatives; • to identify digital transformation opportunities with JDA's solutions.	
		• to recommend how to get to a desired maturity stage through an agile JDA digital transformation roadmap.
Purposes	Descriptive, Predictive	
Target groups	C-level executives	Middle management included
Focus	SC Enterprise level	SC specific Process level
Analysis Areas ("Perspectives")	• People; • Data Core; • Technology; • Digital Change; • Process; • Agile PM.	• Process; • People; • Data Core; • Analytics • Technology; • Digital Change; • Agile PM. Insights and KPIs around every Perspective.
		Note: Process becomes the subject of the assessment.

Technology Focus	IoT, Big Data, ML/AI, Cloud-SaaS (besides traditional technologies)	
Maturity levels	1. Reactive; 2. Anticipate; 3. Proactive; 4. Autonomous.	
Deliverables	• Company's digital maturity assessment; • Summary of "Observations" and "Digital Transformation tips"; • Risk Mitigation Plan.	• Company's specific process digital maturity assessment; • Digital Vision Outline; • Digital Initiatives Summary; • Data Readiness Check; • Digital Agile Roadmap.
Characteristics	EDMM can be seen as a **teaser** to attract new customer for core solutions and *Luminate™* ones or to increase the engagement of mature existing customer for the implementation of the new JDA's offering.	PDMM can be seen as the real element of **differentiation** from other companies, due to its focus on supply chain specific end-to-end processes, on data and advanced analytics/AI.

Figure 45: EDMM & PDMM: differences and similarities

5.2.4 Assessment and Scoring Method

Each process (e.g. Demand Planning, Inventory Optimization) has its own specific assessment with a set of questions for each perspective and related focus areas (e.g. an assessment for inventory optimization with 100 total questions to check the readiness for *Luminate*^{TM} personalized assortment).

The respondent can answer choosing among 4 options (*figure 46*):

- **Nothing;**
- **Basic;**
- **Intermediate;**
- **Advanced**.

A **risk factor** is associated to every answer (*figure 46*):

- “Nothing” is a highest-risk response with a score factor of **10**;
- “Basic” with a score factor of **7**;
- “Intermediate” with a score factor of **4**;
- “Advanced” is the lowest-risk response with a score factor of **0**.

The overall **worksheet is divided** into 7 sections corresponding to the different perspectives (People, Process, etc.).

Every section has 3 columns (*figure 46*):

- “**Weight**”: every question has a specific weight from 1 to 5 based on the importance of the topic;

- “**Readiness Gap**”: it is the overall risk score which is obtained by multiplying the question weight by the answer factor;
- “**Max Score**”: it is calculated by multiplying the weight by 10 times because it is the maximum possible risk score.

Client / Project:	ABC
JDA Consultant:	Mr. XYZ
Date:	12-Sep-18

- View instructions for filling in this worksheet
- View Readiness Scores Summary
- View Mitigation Plan
- View Revision History
- View Approvals

		0/1	factor	Weight	Readiness Gap	Max Score
1.00	**People**					
1.01	**Are roles and responsibilities for Inventory Optimization clearly defined?**			4	0	40
	Nothing	0	10			
	Basic	0	7			
	Intermediate	0	4			
	Advanced	1	0			

Figure 46: Example of Inventory Optimization question (People)

At the end of each section three overall results are computed:

- “**Readiness Gap Score**”: it is the sum of the Readiness Gap of all the questions of a specific section;
- “**Maximum Gap Score**”: it is the sum of the Max Score of all the questions of a specific section;
- “**Scored Gap Percentage**”: it is calculated dividing the Readiness Gap Score by the Maximum Gap Score.

READINESS SCORES

Client / Project:	ABC
Consultant	Mr. XYZ
Date:	12-Sep-18

View Readiness Spider Diagram

View Mitigation Plan

Go back to Readiness Assessment Sheet

		Scored Gap Score	Maximum Gap Score	Readiness Gap %
1	People	710	980	72%
2	Process	550	600	52%
3	Technology	255	860	30%
4	Data Core	130	1110	12%
5	Analytics	280	660	42%
6	Digital Change	620	720	57%
7	Agile PM	480	840	49%
	TOTAL	3025	5770	44.86%

Figure 47: Inventory Optimization Readiness Assessment Results

People Gap Value

0%	to	20%	limited risk
21%	to	40%	moderate risk
41%	to	60%	high risk
61%	to	100%	significant risk

Process Gap Value

0%	to	20%	limited risk
21%	to	40%	moderate risk
41%	to	60%	high risk
61%	to	100%	significant risk

Technology Gap Value

0%	to	20%	limited risk
21%	to	40%	moderate risk
41%	to	60%	high risk
61%	to	100%	significant risk

Data Core Gap Value

0%	to	20%	limited risk
21%	to	40%	moderate risk
41%	to	60%	high risk
61%	to	100%	significant risk

Analytics Gap Value

0%	to	20%	limited risk
21%	to	40%	moderate risk
41%	to	60%	high risk
61%	to	100%	significant risk

Digital Change Gap Value

0%	to	20%	limited risk
21%	to	40%	moderate risk
41%	to	60%	high risk
61%	to	100%	significant risk

Agile PM Gap Value

0%	to	20%	limited risk
21%	to	40%	moderate risk
41%	to	60%	high risk
61%	to	100%	significant risk

Figure 48: Inventory Optimization Readiness Assessment Ranges

As shown in *figure 47* the Total Readiness Gap of the client is calculated, and the cells automatically change color based on modifiable ranges, set by JDA business consultant according to the type of client, the process under analysis and the *Luminate^{TM}* solution considered.

Figure 48 shows the different ranges for the perspectives:

- Green refers to a client who is ready to implement a *Luminate^{TM}* solution, thus the company is in the last digital stage of maturity, called "Autonomous";
- Yellow refers to a client who needs to improve in some focus areas in order to successfully implement a solution ("Proactive" stage);
- Orange means that the client needs to focus and improve most of the perspectives before implementing an advanced solution ("Anticipate" stage);
- Red means that the client is not ready at all to implement advanced solutions ("Reactive" stage).

After a team session with the Strategic Services team, the JDA Business Consultant, based on the client's assessment result and the final decisions obtained during the team meeting, should propose a vision and a transformation roadmap through JDA's software solutions in order to guide the client towards the creation and maturity of the right competencies for digital success.

5.2.5 Result Analysis

The process-focused model was tested in a French manufacturer of automobiles and motorcycles, JDA's client, with an assessment of 124 questions: Demand Planning was the process under analysis since they showed interest for JDA *Luminate*™ Demand Edge.

In the survey there was a comment box to share thoughts on specific question.

Agile PM perspective was not considered for this analysis.

An online survey was used to perform this first trial assessment; therefore, the scoring method for digital maturity stages changes:

- Level 1 "Reactive": 0% - 40%;
- Level 2 "Anticipate": 41% - 65%;
- Level 3 "Proactive": 66% - 85%;
- Level 4 "Autonomous": 86%-100%.

There were 3 respondents:

- 2 **Demand Planning** Project Managers;
- 1 Executive Review Leader (JDA Consultant).

The EU survey methodology used showed the following results:

Perspective	Focus Area	Score	#Questions	Completeness (%)	Level	To check
Process	Digital Use Cases	6	14	42%	2	
	Ecosystem Collaboration	3	6	50%	2	
		9	20	45%	2	
Technology	Process Enabling Solutions	3.33333	7	47%	2	
	Ecosystem Connectivity	3	5	60%	2	
		6.33333	12	52%	2	
Data Core	Availability	3.66667	6	61%	2	
	Quality	3.66667	7	52%	2	
	Platform	3	6	50%	2	
	Strategy and Governance	3	7	42%	2	
		13	26	51%	2	
Analytics	Descriptive	5.33333	6	89%	4	
	Diagnostic	5.11111	7	73%	3	
	Predictive	2.11111	7	30%	1	
	Prescriptive	2	7	29%	1	
		14.5556	27	54%	2	
People	Digital Leadership and Vision	3	4	75%	3	
	Organization Design	4	6	67%	3	
	Talent Mngm and Acquisition	2.11111	4	52%	2	
	Incent. and Reward.Behaviours	2.33333	5	47%	2	
		11.4444	19	60%	2	
Digital Chan	Change Leadership Strategy	4	5	80%	3	
	Culture and Shaping Behaviours	3.33333	5	66%	3	
	Digital Workplace Environment	2.11111	5	42%	2	
	Adaptive Learning	2.66667	5	53%	2	
		12.1111	20	61%	2	

Figure 49: Results from Demand Planning Digital Maturity Assessment

The overall level of Demand Planning digital maturity is 2 (“Anticipate”).

A deeper analysis on individual responses and single Focus Areas shows that there were:

- Terminology misunderstanding;
- Misalignment between respondents’ answers on the same questions;
- Many comments on some questions would make worse the final results.

However, we decided to act qualitatively without changing the scoring methodology but just using the inputs from these comments in order to tease a discussion between the participants.

Before implementing any digital innovation initiatives, the company should establish a roadmap of improvement with the focus on:

- People:
    - Defines roles and responsibilities for each process step;
    - Create relationships with universities and a robust onboarding programs to root new talents in the business;
    - Tie metrics back to financial performance and talent dynamic.
- Digital Change:
    - Enable cross functional teams working with shared objectives/targets;
    - No formal organizational change program exists. Align, train and monitor all employees involved in Demand planning and all key users of JDA Demand Planning solution on Change Management;
    - Allocate resource and budget for digital workplace transformation;
    - Use multiple different education vehicles (e.g. e-learning) in order to provide access to all at scale and build deep sustainable knowledge about Demand Planning.
- Process:
    - Align the forecasts from different teams/functions into one set of numbers;
    - Define standard reports for each process step that must be available in a single repository;

- KPIs need to be implemented and standardized (not only bias measures).

- Technology:
  - Set formal standard KPIs for each step of the process;
  - Set up standard measure for Demand forecasting such as: Forecast Value Add, Weight Mean Absolute Percentage error, Range/Corridor Forecast.
- Data Core and Analytics:
  - Institute a Data Management Team, and form a strategy and vision;
  - There is data quality and insight efforts, but still in silos. Focus on data quality management and implement also ad hoc solvers/add-on solutions;
  - Integrate exogenous data sources;
  - BI and IT teams should involve business stakeholders in the analytics discussion and let them speak from different perspectives in order to identify key business drivers and critical business objectives, and how advanced analytics can support these;
  - Create a data and analytics roadmap to define business initiatives and objectives, milestone (with timetables) resources, with performance measurements and monitoring.

This company has interest in AI but there is risk of overhyping.

It stills needs to make improvements in all the perspectives before implementing JDA *Luminate*^{TM} Demand Edge solutions.

6 CONCLUSIONS

The digital age is radically challenging the traditional notion of how we organize people. Businesses move quickly, markets are continuously disrupted, technology enables quick communication, access to data is abundant and the workforce is more educated than ever. Consumers, customers and partners have heightened expectations around personalization, speed, service and cost. And the advancement of technology continues to automate the most mundane tasks and administration, causing a shift in the role of employees as well as management staff. In a market with lowering margins, increasing complexity, fierce competition and growing customer expectations, being able to quickly respond to changing market needs is key.

This thesis dealt with the topic of Supply Chain Digital Transformation and the maturity models existing in the market that try to assess the digital readiness of an organization's supply chain towards digital initiatives to adapt and stay ahead of competition.

In chapter 2, Digital Supply Chain during Industry 4.0 is described with a detailed overview of its main features and all the related advanced technologies that are blurring the line between the physical and the digital world.

The technologies behind this digital overhaul (such as Internet of Things, Artificial Intelligence, Machine Learning, Blockchain, etc.) are changing and challenging the traditional supply chain management.

In chapter 3, implications which are caused by this digital revolution are highlighted. A big cultural disruption is required since success in this digital journey depends on people - people who are creative, critical thinkers who are comfortable with technology and turning data into insights. Thus, change management and relationship-building skills have become increasingly important to retain talent and effectively integrate the supply chain. High data quality and cybersecurity are other important aspects influencing a company's digital success.

In chapter 4, it is shown JDA Software's approach to supply chain digital transformation through the integration of intelligence and advanced analytics in its product portfolio, called *Luminate*^{TM}, enforced by its partners ecosystem.

All the previous compelling implications highlight the critical need to quantitatively measure the maturity of a supply chain's digital capability. Such measurement will guide future investment in creating or maturing the right competencies for digital success and to assess the effectiveness of investments made in those competencies. Besides building digital competencies over time, supply chains need to create a solid roadmap for building them because the competencies are often related to one another. Understanding the organization's current capabilities is the starting point towards every innovation.

In chapter 5, after having performed some research, either online and in literature, to the best of the knowledge reached, many maturity models have been identified related to Supply Chain Maturity in Industry 4.0. Some of them have been compared and a gap analysis has been performed, which set the basis for the creation of a Digital Supply Chain Maturity Model offering for JDA Software.

Aiming at addressing as many gaps as possible, I decided to create two kinds of maturity models: Enterprise Digital Maturity Model and Process-focused Digital Maturity Model. The former can be seen as a teaser to attract new customer or increase the engagement of existing ones; the latter can be considered the real element of differentiation for JDA Software from other companies since it is an in-depth analysis of different supply chain end-to-end processes.

The models assess, through detailed specific questionnaires, seven core dimensions, called "perspectives". These are: People, Process, Technology, Data Core, Analytics, Digital Change and Agile Project Management.

Every perspective has several sub-areas, called "focus areas".

Four increasing stages of supply chain digital maturity have been defined: Reactive, Anticipate, Proactive, Autonomous. A company can have perspectives with different stages of maturity.

Considering the outputs of these digital supply chain maturity models, a JDA business consultant is able to identify which are the areas the client should focus on for improvements and which innovation *Luminate*^{TM} initiatives, but also traditional JDA's core solutions, should be undertaken. A transformation roadmap is created in order to guide the client towards the next digital maturity level.

JDA's Strategic Services team is currently working on the improvements of these models' offering, and the development of different assessments for specific supply chain end-to-end processes.

Although change is difficult, every organization should establish a plan for advancing their supply chain competencies in order to maintain a competitive edge.

As Peter Senge said, "The only sustainable competitive advantage is an organization's ability to learn faster than the competition.".

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